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THE CONTAMINATION OF BACON BY ARSENIC FROM SMOKE DERIVED FROM PRESERVATIZED WOOD

By C. C. WATSON, Dominion Laboratory, Department of Scientific and Industrial Research, Wellington

(Received for publication, 8 July 1958)

Summary

The contamination of bacon during five hours smoke curing in a pilot plant with smoke obtained from arsenic-treated sawdust was found to be 1·3 to 2·3 p.p.m. (As).

Arsenic penetrated the bacon to a depth of 3cm from the exposed meat surface. Negligible penetration occurred from the skin surface.

Of the total arsenic in the sawdust 8·6% was evolved during combustion and of this amount 6·4% left the fire box and distributed to the smoking chamber (3·5% deposited) and the exhaust pipe (2·9% in smoke).

INTRODUCTION

As large quantities of sawn timber are treated with arsenical preservatives to prevent termite and fungal attack, an examination of the volatility of arsenic was undertaken, to determine the possible contamination of bacon during smoking occasioned by use of sawdust from arsenic-impregnated timber.

A preliminary examination showed that the temperature of smouldering sawdust at the burning zone was in the vicinity of 415° C. Arsenic compounds volatile below this temperature include three allotropes of arsenious oxide and the chlorides and fluorides in both the trivalent and pentavalent state. In addition, arsenic oxide may be reduced to arsenic by carbon monoxide and volatilized at temperatures as low as 60° C. (Vickery and Edwards, 1947).

During an examination of the combustion of arsenical sawdust, Curzon and Eisner (1953) found that only 5% of arsenic remained

in the ash, suggesting 95% volatilized during combustion.

From these results and the variations found by Thomas and Collier (1945) in the volatility of arsenic in tobacco smoke it is evident that the volatility depends largely on the combustion conditions.

A pilot-scale plant, in which the smoke density and temperature could be varied and continuously recorded, was used to determine the amount of arsenical contamination which occurred in bacon cured with smoke from arsenical sawdust.

REAGENTS

All the reagents used were of analytical grade. Concentrated nitric acid was AsT grade, and the quantities used in the digestion contained negligible arsenic.

EXPERIMENTAL

Sawdust used in this work (10 to 60 mesh) was obtained from *Pinus radiata* sapwood treated with a 1·08% solution of Boliden S-25 preservative. Analysis of air dry samples showed a content in the wood of 0·233% arsenic.

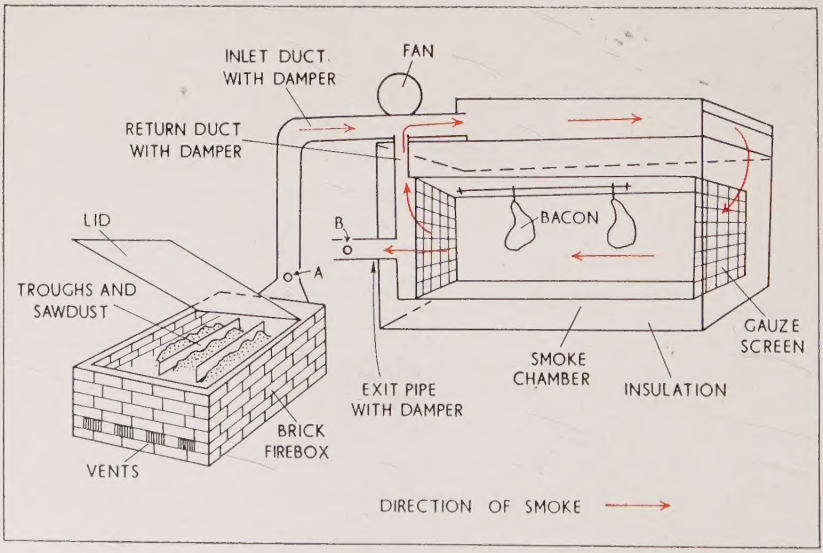

FIG. 1.—Sketch of pilot plant.

The pilot plant (Fig. 1) included a brick fire box fitted with a fine steel mesh grate divided into troughs by metal strips. A steel tray was used under the grate to collect the ash, a flat steel cover formed the lid and the air intake was controlled by vents in the brickwork below the grate. Sawdust was spread evenly in the troughs, ignited and allowed to smoulder. The smoke was conveyed through a pipe fitted with dampers to the bacon chamber at a rate of 400 litres/min. and cycled by a fan continuously through the chamber at a rate of 8,500 litres/min.

Most of the smoke would circulate through the chamber nineteen times before passing out of the exit tube.

The smoke density in the chamber was measured by a photo-electric cell and recorded graphically. The average density of the smoke for the whole smoking time was equivalent to an optical transmission of 80% with a light path length of 18 ins.

Sampling

A set of three Dreschel bottles, each fitted with a fine sinter diffuser was used to collect the smoke samples at each sampling point. The first bottle contained 50% nitric acid, the second distilled water, and the third 10% alcoholic potassium hydroxide solution. Smoke was drawn through the bottles at the rate of 2 litres/min. as measured by flowmeter.

To indicate the levels of arsenic deposition on wet and dry surfaces within the chamber, both wet and dry filter paper discs were suspended at various points. As the temperature in the chamber was 107° F it was necessary to wet some papers with saturated calcium chloride solution to prevent them from drying.

Analytical Methods

All samples were digested by the wet oxidation procedure with nitric-sulphuric acid mixture and where sufficient sample was available several aliquots from each digestion were analysed.

Some difficulty was found in digesting bacon samples by wet oxidation, due to the large amounts of fat present.

After the initial frothing had subsided and the meat was in solution the fat appeared on the surface and could be removed by diluting with 50 ml of water, heating to bring it to the surface, allowing it to solidify in an ice bath and then decanting the liquor. The remaining fat was then washed with water and discarded and the washings were added to the aqueous liquor. The digestion was then continued. It was found by adding standard quantities to the digestion that the arsenic was present in the aqueous layer and that no loss occurred by removing fat in this manner.

Macro quantities of arsenic were determined in the ash and wood samples by reduction with hypophosphorous acid and titration with standard potassium bromate. (Anon, 1954).

Micro quantities of arsenic were analysed by the molybdenum blue method using the special distillation apparatus of Magnuson and Watson (Bartlett, Wood, and Chapman, 1952).

The molybdenum blue complex was measured with a Beckman spectrophotometer at 840mμ and it was found that the analysis range could be extended to 70μg of arsenic by increasing the volume of 30% potassium bromide in the distillation from 2 to 3 ml. A summary of the errors in this method and the precautions necessary to correct them is given by Gunther and Blinn (1955).

RESULTS

All arsenic figures have been calculated as elemental arsenic.

Arsenic in Smoke

Smoke was collected at each point at a uniform rate, the amount being equivalent to 0·5% of the whole volume of smoke from the fire box.

For analysis, the bottles containing the nitric acid and distilled water were combined. Arsenic content of the alcoholic potash solution of the third bottle at the point A (Fig. 1), where maximum arsenic was expected, showed a negligible quantity (less than 8μg) and therefore the remaining alkaline absorbing bottles were not analysed.

The quantities of arsenic obtained from the smoke at the two sampling points are given in Table 1.

TABLE 1.—Arsenic in Smoke.

Duration of sampling (min.)	Position of sampling (Fig. 1)	Arsenic (μg)
300	A	145·5 ± 2
290	B	66·0 ± 2

The quantities of arsenic in the wood, ash, and total quantity of smoke passed through the smoking chamber, are given in Table 2.

TABLE 2.—Arsenic Content of Wood, Ash, and Smoke.

Arsenic	Calculated as	
	% of Sawdust	% of Arsenic in Sawdust
In Sawdust	0·233	—
In Ash	0·213	91·4
Volatilized	0·02	8·6
In smoke at A	0·0013	0·56
In smoke at B	0·0006	0·26

Table 2 shows that 8·6% of the total arsenic in the wood was evolved during burning. Of this amount 6·4% reached the first collecting point A after which 3·5% was deposited in the pipes and smoking chamber and the remaining 2·9% appeared in the exhaust pipe at B.

Arsenic in the Smoking Chamber

Filter paper discs were suspended on the walls of the smoking chamber to determine the deposition of arsenic from the smoke. The position of the discs was not significant as approximately the same level of arsenic was found on discs at the top, bottom, and sides of the chamber.

Discs which were kept moist with saturated calcium chloride solution absorbed twice as much arsenic as dry discs.

Table 3 gives the analyses of paper discs.

TABLE 3.—Arsenic Deposition on the Paper Discs in the Smoking Chamber.

Sample	Total As found (μg)	Surface concentration ($\mu g/cm^2$)
W1	37	0·105
W2	41	0·116
D1	16·5	0·046
D2	18·0	0·051
D3	14·5	0·041
D4	20·5	0·058

D = Dry W = Wet

Two shoulders of bacon were suspended in the smoking chamber to ascertain the deposition and penetration of arsenic into the meat. One shoulder was dried for 12 hours in the chamber before smoking and the other was used in its natural moist condition. After smoking, a cross-sectional piece, free of bone and containing as much meat as possible, was cut from each shoulder. The quantities of arsenic found in these samples and in a control sample of bacon are given in Figs 2, 3, 4.

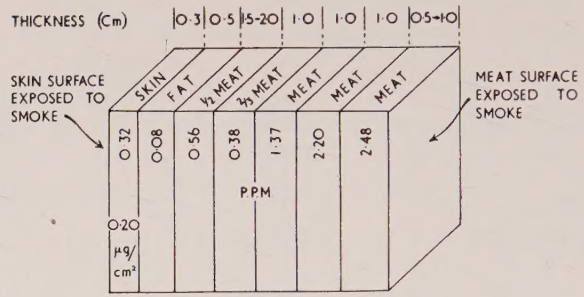

FIG. 2.—Wet shoulder of bacon. Additional samples of skin from the shoulder gave values of 0·20 and 0·45μg/cm^2.

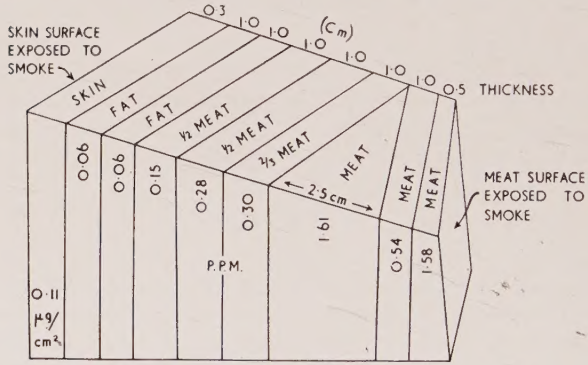

FIG. 3.—Dry shoulder of bacon. More variation was found with the dry shoulder in the arsenic content of the skin which gave values of 0·26, 0·38, 0·11, 0·15, and 0·17μg/cm^2.

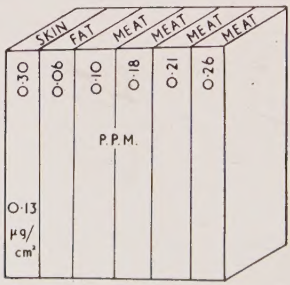

FIG. 4.—Control bacon.

Additional skin samples were taken from each shoulder for analysis and results are given as micrograms of arsenic per unit of surface area.

It is evident from Figs 2 and 3 that, except for an occasionally high or low value, there is an even gradation of arsenic in the meat and that arsenic from the smoke penetrated the bacon to a distance of approximately 3 centimeters from the surface of the meat in both the wet and dry samples, but negligible penetration occurred from the skin surface.

Arsenic content of the meat from the moist bacon was approximately 50% greater than the content from the dry bacon. The maximum quantities of arsenic found, after subtracting the highest blank value of the control bacon, were within the range 1·3 to 2·3 p.p.m. (As).

Deposition of arsenic on the skin varied considerably but the maximum figure did not exceed 0·5 p.p.m. after allowance was made for the control.

CONCLUSION

Controlled burning of sawdust from wood treated with arsenical preservatives caused the evolution of 8·6% of the arsenic in the timber. Most of this arsenic was deposited close to the fire but the remainder was sufficiently volatile to travel a considerable distance and contaminate the bacon in the smoking chamber. The amounts of arsenic found in the bacon show that the use of such sawdust in the smoke-curing of bacon presents a toxicity hazard and should be avoided.

ACKNOWLEDGEMENTS

Thanks are expressed to the Chemical Engineering Section, Dominion Laboratory, D.S.I.R., for the use of the bacon smoking plant and to Mr C. F. Denmead for advice and assistance with this apparatus.

REFERENCES

ANON., 1954: *Proc. Amer. Wood Pres. Ass. 50* : 96.

BARTLETT, J. C.; WOOD, M.; CHAPMAN, R. A., 1952: Determination of Arsenic in Fruits and Vegetables. *Analyt. Chem. 24* : 1821-4.

CURZON, G. E.; EISNER, H. S., 1953: An Assessment of the Hazard caused by Arsenious Fumes from Impregnated Timber in Underground Fires. *Safety-in-Mines Res. Establ. Res. Rep. 78.*

GUNTHER, F. A.; BLINN, R. C., 1955: "Analysis of Insecticides and Acaricides". pp. 302-5. Interscience, New York, 696 pp.

THOMAS, M. D.; COLLIER, T. R., 1945: The Concentration of Arsenic in Tobacco Smoke Determined by a Rapid Titrimetric Method. *J. industr. Hyg. 27* : 201-6.

VICKERY, R. C.; EDWARDS, R. W., 1947: The Reduction of Arsenic Trioxide by Carbon and Carbon Monoxide. *Metallurgia Manchr., 36* : 3-6.

THE CONTAMINATION OF FISH BY ARSENIC FROM SMOKE DERIVED FROM PRESERVATIZED WOOD

By C. C. Watson, Dominion Laboratory, Department of Scientific and Industrial Research, Wellington

(Received for publication, 8 July 1958)

Summary

An experimental smoking of fish was conducted using shavings from wood treated with arsenical preservatives as the source of smoke.

During burning 22% of the arsenic in the wood shavings was volatilized. Uptake of arsenic in the fish was as high as 25 p.p.m.

Introduction

In a previous paper (Watson, 1958) a study was undertaken to determine the contamination of bacon caused by arsenic from preservatized timber during smoking. It was shown that arsenic from the burning of treated sawdust was volatile and penetrated some distance into the meat, but did not penetrate the fat layer.

This investigation has now been extended to include fish, in which arsenic penetration was expected to be greater because of the smaller thickness of the pieces and lower fat content.

As fish is usually smoked in smaller quantities than bacon, the smoke-house described in the previous paper was not used. A commercial smoke-house, in which batches of about a thousand pounds of fish are smoked, was examined and a small-scale plant was constructed.

The amount of smoke required to cure fish to the desired colour depends on the size of the chamber, the quantity of fish, and the outside temperature. Cold wet weather causes the smoke to settle so that it does not reach the top racks of fish. The amount generated depends on the density of the wood and the inlet draught rate.

The colour of the smoked fish gives an indication of the amount of smoke absorbed. Excess smoking gives a dark colour, and insufficient a pale yellow colour. Samples of fish were smoked in the pilot plant until a satisfactory colour was obtained.

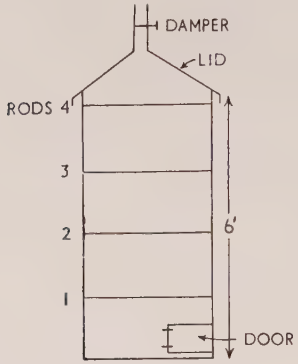

FIG. 1.—Smoking chamber.

EXPERIMENTAL

The pilot plant (Fig. 1) was made by welding two oil drums together on end and fitting a door in the side at the base. A conical hood, having a small, damper controlled vent, was placed on the top of the chamber and four rods were inserted through the drums radially at various heights in order to suspend the pieces of fish in the smoke.

Several blue cod which had been salted in brine were cut into small pieces and weighed. The wet pieces, each of approximately 100 grams were hung by hooks in the chamber three or four to each rod.

Air-dry shavings from *Pinus radiata* sapwood treated with Boliden S-25 arsenical preservative, were placed in the chamber and ignited. The flames were then extinguished and the shavings allowed to smoulder.

Two smoking trials were conducted and in each, additional amounts of shavings were added periodically to maintain the smoke. In the first experiment the fish reached a deep yellow colour after 6 hours and a total of 2 lb of shavings was used. In a second smoking trial a lighter yellow colour was attained after $4\frac{1}{2}$ hours smoking and the use of $1\frac{3}{4}$ lb of shavings. The samples were removed, weighed to record the loss in moisture, and stored in air-tight jars prior to analysis. After both smoking trials had been concluded the ash was collected and sieved (10 mesh) to remove the unburnt shavings.

The methods of analysis used for the ash, wood, and fish samples were described in the previous paper (Watson, 1958).

Sections cut from the ends and centre of a sample of the smoked fish showed an even distribution of arsenic throughout the piece. A 20 gm section of each piece of smoked fish was then digested with concentrated nitric and sulphuric acids. The small quantity of oil in

the fish prolonged the digestions, but was not sufficient to require separation as in the case of the fat from bacon.

After digestion, the sample was made to a standard volume of 50 ml and three aliquots of this solution were used for the micro-determination of arsenic.

RESULTS AND DISCUSSION

Table 1 shows the amounts of arsenic found (in terms of elemental arsenic) in the smoked fish from the two experimental trials.

TABLE 1.—Arsenic Content of Smoked Fish

Time of smoking (hours)	6		$4\frac{1}{2}$	
Wt of shavings (lb)	2		$1\frac{1}{4}$	
Position in chamber (Bar No.)	Arsenic* p.p.m.	Average error *a*	Arsenic* p.p.m.	Average error *a*
1	16·1	0·5	26·8	0·3
1	15·1	1·3	13·5	0·2
1	18·7	3·2	22·2	0·6
1	—	—	19·2	0·1
2	24·9	0·1	21·1	0·3
2	26·1	0·5	22·8	0·3
2	—	—	19·3	0·8
3	20·0	1·1	17·1	0·1
3	23·7	0·0	23·4	0·6
3	17·5	0·3	16·5	0·2
4	28·1	0·7	21·4	0·0
4	24·0	0·1	18·4	0·0
4	20·0	0·5	17·8	0·0
4	21·2	0·3	—	—

*Based on the weight of fish after smoking. Loss in weight during smoking varied from 16·0% to 28·4%.

$$\text{Average error } a = \pm \frac{\Sigma(d)}{n}$$

where d is the deviation of a single observation from the mean (without sign), and n the number of determinations.

Table 2 shows the natural arsenic content of blue cod, calculated on the wet and dry weight, the latter was found from the average loss in weight of similar pieces of fish during smoking.

TABLE 2.—Natural Arsenic Content of Blue Cod

Sample	Wet Weight (g)	Dry Weight* (g)	Arsenic p.p.m. On Wet Wt	On Dry Wt
Tail piece	106	79	0·7	0·8
Gill piece	105	82	1·2	1·5

*Calculated weight.

The arsenic content of the shavings and ash was determined and both results are given in Table 3.

TABLE 3.—Arsenic Content of Shavings and Ash

	Arsenic Content as	
	% of shavings	% of Arsenic in shavings
Shavings	0·388	—
Ash	0·301	77·6
Volatilized	0·087	22·4

Considerably more arsenic was volatilized (22·4%) from the shavings than in the previous experiment with bacon (8·6%). The shavings used were obtained from wood which had been treated to a retention of total preservatives of approximately 0·4 lb/cu. ft, whereas in the earlier experiment sawdust treated to a retention of 0·25 lb/cu. ft of preservative was used.

It was estimated that about 100 lb of shavings would be used in the commercial smoke-house for the smoking of 1000 lb of fish. With shavings containing 0·388% of arsenic 0·087 lb would be liberated in the smoke-house. The maximum amount of arsenic deposited on the fish would then be 87 p.p.m., assuming that no deposition occurred on the walls of the chamber or escaped with the smoke. It appears that, in practice, considerably less than this amount would be found in the fish, but the figure might reach 25 p.p.m.

CONCLUSION

Shavings or waste from arsenical preservatized timber should not be used in the smoking of fish either alone or mixed in small amounts with other shavings, as this would lead to the contamination of the fish with arsenic and create a considerable toxicity hazard.

ACKNOWLEDGEMENT

The author wishes to thank Mr D. Meo for advice concerning the commercial smoking of fish.

REFERENCE

WATSON, C. C., 1958: *N.Z. J. Sci 1* : 361-8.

MERCURY CONTENT OF TOMATOES

By H. M. Stone and P. J. Clark, Dominion Laboratory, Department of Scientific and Industrial Research, Wellington

(Received for publication, 15 July 1958)

Summary

Determinations were made of the mercury content of the skin, and of the pulp of untreated tomatoes and of tomatoes sprayed with Aerocide P.M.4, a phenyl mercuric salicylate aerosol. The total mercury content of untreated tomatoes ranged from nil to 0·044 p.p.m., and of treated tomatoes from 0·010 p.p.m. to 0·075 p.p.m. Analysis of the results showed that at the 90% confidence level, 17·3% of fruit from treated glasshouses would contain more than 0·05 p.p.m. mercury, but where the number of applications was restricted to 7, only 1% of treated samples would be expected to exceed 0·05 p.p.m.

Introduction

Since the figures for residual mercury on the skins of tomatoes were published (Stone *et al.*, 1954) it has been shown that apples treated with mercury sprays contain mercury in the pulp as well as in the skin (Stone *et al.*, 1957). It was, therefore, considered advisable to re-examine the distribution of residual mercury in treated tomatoes. Subsequently, Beidas and Higgons (1957) have shown that there was more residual mercury in the pulp than in the skin.

Tomatoes used in these experiments were grown in commercial glasshouses in the Auckland district and had been sprayed with Aerocide P.M.4, a proprietary preparation containing 0·56% phenyl mercuric salicylate, as described previously (Stone *et al.*, 1954). Dosage was at the rate of one shot (40 ml) to 5,000 cu. ft.

Because of the varying rate of development of fruit on a truss, the exact number of applications received by fruit picked at any one time was difficult to determine. The number of applications recorded in the tables, therefore, refers to the number of treatments that the plants received and the later pickings of fruit may have received less than that number. The fruit was picked when just coloured.

Untreated tomatoes were obtained from commercial glasshouses in Auckland and from home gardens in Wellington and Christchurch.

Experimental

The methods of digestion and analysis were by modifications (Stone *et al.*, 1954) of the method of Klein (1952), using approximately 500g of sample. Preliminary extractions with hot 5% nitric acid and with hot water showed that the nitric acid treatment removed only

some of the mercury from the skin, and that the hot water treatment removed none. The tomatoes, therefore, were dipped in hot water (temp. *c* 90° C), the skins removed cleanly from the pulp, and both skin and pulp analysed separately.

The mercury content of treated tomatoes, expressed as p.p.m. on the weight of the whole fruit, is shown in Table 1. The samples are grouped according to the number of spray applications received.

TABLE 1.—Mercury Content of Treated Tomatoes

Glasshouse	No. of applications	Mercury in skin (p.p.m.)	Mercury in pulp (p.p.m.)	Total mercury (p.p.m.)
A	8	0·000	0·016	0·016
	9	0·005 0·011	0·009 0·012	0·014 0·023
	10	0·001	0·012	0·016
B	6	0·009	0·020	0·029
	8	0·007	0·028	0·035
	11	0·007	0·014	0·021
	13	0·010	0·034	0·044
C	14	0·005	0·035	0·040
	17	0·010 0·015	0·040 0·026	0·050 0·041
Miscellaneous	2	0·001	0·009	0·010
	3	0·003	0·008	0·011
	6	0·006 0·006	0·011 0·013	0·017 0·019
	10	0·006	0·022	0·028
	11	0·002	0·053	0·055
	12	0·018	0·057	0·075
	14	0·009	0·046	0·055
	16	0·010	0·044	0·054

The mercury content of untreated tomatoes is shown in Table 2.

TABLE 2.—Mercury Content of Untreated Tomatoes.

Mercury content of skin (p.p.m.)	Mercury content of pulp (p.p.m.)	Total mercury (p.p.m.)	Mercury content of skin (p.p.m.)	Mercury content of pulp (p.p.m.)	Total mercury (p.p.m.)
0·000	0·000	0·000	0·006	0·006	0·012
0·001	0·001	0·002	0·002	0·012	0·014
0·000	0·002	0·002	0·003	0·011	0·014
0·001	0·003	0·004	0·005	0·009	0·014
0·003	0·002	0·005	0·008	0·008	0·016
0·000	0·005	0·005	0·005	0·014	0·019
0·003	0·003	0·006	0·001	0·020	0·021
0·004	0·004	0·008	0·005	0·017	0·022
0·002	0·009	0·011	0·012	0·015	0·027
0·002	0·009	0·011	0·010	0·034	0·044

Recovery determinations were made on skin and pulp of a sample which, by previous analysis, had been shown to contain no mercury. Known amounts of standard mercuric chloride solution added to the tomato skin, and to the pulp before digestion gave recoveries of 95 to 100% from the skin and 85 to 100% from the pulp. The figures in the tables are uncorrected.

DISCUSSION

The bracketed figures in Table 1 represent analyses of duplicate digestions of larger samples and illustrate the sampling error involved with samples.

The highest amount found, 0·075 p.p.m., is considerably lower than the maximum reported by Beidas and Higgons (1957), whose figures ranged from nil to 0·55 p.p.m. The spray formulations, however, were different and the amount used by these authors gives a concentration of mercury in the glasshouse during spraying of 1·2μg per litre, whereas the present work follows the standard practice in New Zealand, which gives a concentration of 0·75μg per litre. With untreated tomatoes, Beidas and Higgons (1957) found no mercury, whereas in the work reported here only one sample of 20 examined contained no mercury and the highest content was 0·044 p.p.m.

An analysis of the results is given in Table 3, where the mean in parts per million of mercury in the skin, in the pulp, and in the whole fruit, for both untreated and treated fruit is shown.

TABLE 3.—Statistical Analysis of Results, Mercury in p.p.m.

	Untreated	Treated	Mean diff.	Standard deviation of diff.	"*t*"-value	Level of significance
Skin	0·0036	0·0072	0·0036	0·0172	0·21	> 10%
Pulp	0·0092	0·0255	0·0163	0·0032	5·09	< 0·1%
Whole fruit	0·0128	0·0327	0·0199	0·0066	3·02	< 1%

Table 3 shows that there appears to be twice as much mercury in the skin of the treated tomatoes as in that of the untreated but the difference is not significant at the 10% level owing to the high variability of the figures. Figures for the pulp and the whole fruit show that the differences between untreated and treated fruit are significant and that mercury sprays have increased the mercury content of the fruit.

As all fruit examined in Table 1 was just ripening it would be representative of treated glasshouse tomatoes reaching the market, and from the analysis of the results it is possible to assess the proportion of such fruit that would exceed a certain fixed tolerance for mercury. The American limit (Anon, 1955) is nil but with figures such as those shown in Table 2 for untreated tomatoes it is obvious that New Zealand would not be able to comply with this limit.

It has been suggested (Stone *et al.*, 1954) that the mercury residue on tomatoes calculated from the skin content should not exceed 0·05 p.p.m., but it is clear from this further investigation that any limit for mercury in tomatoes must refer to the total mercury content.

Using the total mercury figures given for the tomatoes, Table 4 shows the expected number of samples per thousand that would be above tolerances of 0·05 p.p.m. and 0·06 p.p.m. at the 90% confidence level.

TABLE 4.—Expected Number per Thousand above Tolerance Level

Tolerance level (p.p.m.)	Treated fruit		Untreated fruit	
	Expected No.	Limits	Expected No.	Limits
0·05	173	238 to 99	2	6 to < 1
0·06	68	147 to 29	< 1	< 1

From Table 4 it can be seen that there is a 90% chance of being correct that between 238 and 99 per thousand of fruit from treated glasshouses would contain more than 0·05 p.p.m. of mercury, the actual figure estimated from the data in these experiments being 173 per thousand.

From this conclusion the question arises as to whether limiting the number of applications would be effective in reducing the chances of samples exceeding 0·05 p.p.m. residual mercury. Results of statistical examination are shown in Table 5.

Table 5.—Expected Number of Samples Exceeding 0·05 p.p.m.

No. of applications	No. of samples per thousand expected to exceed 0·05 p.p.m.
10	100
8	50
7	10
5	2

It is clear that multiple mercury spray applications can give rise to appreciable mercury residues in tomatoes and thus constitute a hazard to the consumer, but restriction of the number of applications considerably reduces this risk. It has been suggested (Reith, 1955) that a tolerance for mercury should be allowed in fruit and vegetables of not more than the natural mercury content which this author put, in some instances, as high as 0·05 p.p.m. A similar figure was recommended as a practicable tolerance for apples (Stone *et al.*, 1957). If this tolerance were applied to tomatoes in New Zealand, then it is clear from the figures in Table 5 that the number of mercury sprays applied to tomatoes would have to be restricted to seven or less to minimise the risk of exceeding this figure.

Acknowledgements

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References

Anon., 1955: *Federal Register, U.S.A., 20* : 1498.

Beidas, A. S.; Higgons, D. J., 1957: Mercury Residues in Sprayed Crops. I—Tomatoes. *J. Sci. Fd. Agric., 8* : 597-600.

Klein, A. K., 1952: Report on Mercury. *J. Ass. off. agric. Chem. Wash., 35* :537.

Reith, J. F., 1955: Toxic Trace Elements in Food, III. *Voeding, 16*: 932.

Stone, H. M.; Clark, P. J.; Jacks, H., 1954: Mercury Residues on Tomatoes. *N.Z. J. Sci. Tech., B35* : 301-6.

———, 1957: Mercury Content of Apples. *N.Z. J. Sci. Tech., B38* : 843-8.

DETERMINATION OF DIPHENYLAMINE RESIDUES ON APPLES

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(Received for publication, 15 July 1958)

Summary

A method for the determination of diphenylamine residues on apples is based on the colorimetric determination of the blue oxidation product produced with vanadium pentoxide in sulphuric acid. Beer's law is obeyed over the range 10 to 80μg.

Introduction

Following the introduction by Smock (1957) of diphenylamine as an agent for the control of apple scald, a rapid and accurate method was required for its determination on the skin and in the pulp of apples.

Methods have been described for the determination of micro-amounts of diphenylamine in salt water, nitrocellulose powders, air, dyes, and apples. Hofmann (1864) found that diphenylamine on treatment with an oxidizing agent in a strongly acid solution yielded a blue product, which appears to be a salt of diphenylbenzidine. This reaction has been widely used for the determination of diphenylamine or the oxidizing agent (Snell and Snell, 1949). Thiel (1929) considered that the best oxidizing agent was ferric sulphate in sulphuric acid; Barnes (1944) and Norvall *et al.* (1948) used potassium dichromate in sulphuric acid; Barlot (1954) sodium nitrate with sodium nitrite in sulphuric acid, and Phillips (1952) and Yatsu (1956) vanadium pentoxide in sulphuric acid.

Two methods that depend on the colour reaction when diphenylamine is coupled with a diazonium salt have also been described. Ponomarenko (1947) determined diphenylamine by reaction with diazotised sulphanilic acid in acid solution, and Bruce *et al.* (1957) by coupling with diazotised 2, 4-dinitroaniline in phosphoric acid.

Kolsek (1953) measured photometrically the red-violet colour formed by diphenylamine with lead dioxide in the presence of acetic acid.

Clements and Harrow (1952) and Bruce *et al.* (1957) determined diphenylamine by measuring the absorption at three wavelengths in the ultraviolet.

Yatsu's method was developed for the determination of diphenylamine residues on apples, but this was unsatisfactory because interfering colours were produced from extraneous substances not removed from the extracts. As a consequence, the following procedure was developed.

REAGENTS

Acetone 70% (v/v)
Benzene, AnalaR
Petroleum ether, b.p. 40° to 60° C, AnalaR
Sodium hydroxide 10% (w/v)
Sulphuric acid—vanadium pentoxide reagent
0·05mg V_2O_5 per ml of 50% (v/v) H_2SO_4
Diphenylamine, AnalaR
Dow Corning antifoam "A" emulsion
Magnesium oxide (chromatographic quality)

EXTRACTION

Weighed peelings from a known weight of apples (600 to 800g) were placed in a B34 standard joint flask and 2 ml of petroleum ether was added for each gram of peelings. The stoppered flask was shaken mechanically for 30 min., the petroleum ether extract was filtered, and an aliquot containing 25 to 50μg of diphenylamine was concentrated to about 10 ml by evaporation on a steam bath. This solution was run on to a column (40 x 15 mm) of magnesium oxide, and the diphenylamine was eluted with 40 ml of 1:1 benzene—petroleum ether. The eluate was concentrated on a steam bath to about 5 ml, transferred to a stoppered test-tube, and diluted to 10 ml with petroleum ether.

For the pulp the extraction technique was modified. The pulp sample of about 250g was blended for 2 min. with 150 ml of 70% acetone and transferred to a 1 litre separatory funnel with 20 ml of 70% acetone. The pulp suspension was cooled, shaken vigorously with four 150 ml portions of petroleum ether and finally centrifuged with 70 ml of petroleum ether. The petroleum ether extracts were filtered, combined, concentrated to about 30 ml on a water bath using a Snyder column, and transferred quantitatively with small amounts of petroleum ether to a steam distillation unit. About 25 ml of water and 1 ml of 10% sodium hydroxide were added and the mixture was steam-distilled. The outlet of the condenser dipped into a little petroleum ether contained in a separatory funnel, and about 250 ml of distillate was collected. Foaming could be prevented by the addition of one drop of silicone antifoam compound. The distillate was extracted four times with 60 ml portions of petroleum ether, and

the combined extracts were concentrated by distillation through a Snyder column. An aliquot, containing 25 to 50μg of diphenylamine, was diluted to 10 ml with petroleum ether in a stoppered test-tube.

COLOUR DEVELOPMENT

Ten millilitres of the sulphuric acid—vanadium pentoxide reagent was added to the extract in a stoppered test-tube, and the tube was shaken vigorously for 30 sec. and centrifuged for 2 min. The sulphuric acid layer was pipetted into a 1cm cell and the optical density measured against the sulphuric acid—vanadium pentoxide reagent at 590mμ. Readings were taken 5 to 7 min. after the addition of the sulphuric acid—vanadium pentoxide reagent.

STANDARDS

Standard solutions of diphenylamine containing 1mg per ml, 100μg per ml, and 10μg per ml were prepared in petroleum ether (b.p. 60° to 80° C, AnalaR). A standard curve was prepared by adding 10 to 80μg quantities of diphenylamine to stoppered test-tubes and carrying out the colour development. Beer's law was obeyed over this range.

RECOVERIES

Several varieties of untreated apples were peeled and known amounts of diphenylamine standard (150-1,300μg) were added to the peelings before extraction with petroleum ether. The recoveries obtained are given in Table 1.

The mean recovery from all varieties was 94%. Peelings from control apples similarly processed gave an apparent diphenylamine content of 0 to 10μg.

In recovery determinations on the pulp, peeled apples were taken and known amounts of diphenylamine (70 to 250μg) were added to the fruit in the blender before pulping. The recoveries obtained are given in Table 2.

The mean recovery was 86%. Pulp from control apples similarly processed gave an apparent diphenylamine content of 1 to 1·5μg.

DISCUSSION

The absorption spectrum of the blue colour formed has a broad maximum over the range 582 to 592mμ.

Yatsu (1956) prepared the standard curve by evaporating an aliquot of diphenylamine standard almost to dryness in a test-tube under a gentle stream of air. The sides of the tube were washed down with about 0·5 to 1·0 ml of pentane, and 10 ml of sulphuric acid—

TABLE 1.—Recovery of Known Amounts of Diphenylamine from Apple Skins

Apple Variety	Diphenylamine Added (μg)	Diphenylamine Found (μg)	Recovery %
Granny Smith	0	6	—
Granny Smith	0	10	—
Granny Smith	0	4	—
Granny Smith	150	159	106
Granny Smith	300	280	93
Granny Smith	500	490	98
Granny Smith	500	465	93
Granny Smith	800	736	92
Granny Smith	1,000	900	90
Granny Smith	1,000	967	97
Granny Smith	1,300	1,223	94
Sturmer	0	3	—
Sturmer	500	475	95
Sturmer	600	610	102
Statesman	0	3	—
Statesman	500	446	89
Statesman	900	780	87
Delicious	0	9	—
Delicious	200	178	89
Dougherty	0	0	—
Dougherty	700	668	95
Frimley Beauty	0	7	—
Frimley Beauty	500	495	99
Frimley Beauty	500	450	90
Rome Beauty	0	0	—
Rome Beauty	500	445	89

TABLE 2.—Recovery of Known Amounts of Diphenylamine from Apple Pulp

Apple Variety	Diphenylamine Added (μg)	Diphenylamine Found (μg)	Recovery %
Granny Smith	0	1	—
Granny Smith	0	1·5	—
Granny Smith	70	62	89
Granny Smith	100	81	81
Granny Smith	120	109	91
Granny Smith	150	132	88
Granny Smith	150	123	82
Granny Smith	250	210	84

vanadium pentoxide reagent was added. After shaking and centrifuging the solution, the transmission was read on a spectrophotometer at 600mμ four minutes after the addition of the sulphuric acid reagent. Yatsu reported a variation of 20% about the mean. In the present work it was found that this variation was caused by loss of diphenylamine during evaporation in a stream of air. The variation of the standard curve about the mean was reduced to 6% if the

evaporation step was omitted and the volume adjusted to 10 ml by the addition of petroleum ether. The standard solutions were made up in petroleum ether, b.p. 60° to 80° C, instead of b.p. 40° to 60° C as there was less risk of evaporation during pipetting. Benzene added to the petroleum ether aliquot of diphenylamine did not affect the extinction coefficient. The blue colour developed from the standards was stable for at least 30 min., but that from apple extracts showed variable stability after 8 min. It was therefore necessary to determine the absorption of the coloured solutions 5 to 7 min. after the addition of the sulphuric acid—vanadium pentoxide reagent.

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References

Barlot, J., 1954: Colorimetric Determination of Diphenylamine in LB. 7T and LB. TU Powders. *Membres Poudres, 36* : 199-207.

Barnes, H., 1944: Estimation of Small Quantities of Diphenylamine. *Analyst, 69* : 344.

Bruce, R. B.; Howard, J. W.; Zink, J. B., 1957: Determination of Diphenylamine Residues on Apples. (Paper delivered at the 131st National Meeting of the American Chemical Society.)

Clements, J. E.; Harrow, L. S., 1952: Determination of Diphenylamine in Extract D & C Yellow No. 1 and Extract D & C Yellow No. 2. *J. Ass. off. agric. Chem., Wash. 35* : 159-61.

Hofmann, A. W., 1864: *Liebigs Ann., 132* : 165.

Kolsek, J., 1953: Photometric Determination of Anesthesine and Certain Aromatic Amines with the Aid of the Lauth Reaction. *Z. anal. Chem., 140* : 426-9.

Norvall, J. G.; Ovenston, T. C. J.; Parker, C. A., 1948: The Colorimetric Determination of Diphenylamine in Nitrocellulose Powders. *Analyst, 73* : 389-93.

Phillips, W. F., 1952: Colorimetric Estimation of Residual Benzene Hexachloride. *Analyt. Chem., 24* : 1976-9.

Ponomarenko, B. V., 1947: Colorimetric Determination of Small Quantities of Diphenylamine in Air. *Zavodskaya Lab., 13* : 937-41.

Smock, R. M., 1957: A Comparison of Treatment for Control of the Apple Scald Disease. *Proc. Amer. Soc. hort. Sci., 69* : 91-100.

Snell, F. D.; Snell, C. T., 1949: "Colorimetric Methods of Analysis". 3rd ed., Vol. II, Inorganic, pp. 458, 796, D. Van Nostrand Company, New York, 950 pp.

Thiel, A., 1929: Diphenylamine and Diphenylamine Blue. *Z. Elektrochem., 35* : 274-8.

Yatsu, L., 1956: Diphenylamine Residues on Apples. *Cornell Mimeograph*, S-457c.

NOTES ON SETTLEMENT IN *LEPAS* BARNACLES

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Summary

Examination of a large number of adult populations of *Lepas anatifera* L. and *L. australis* Darwin attached to floating survey beacons has shown that these barnacles settle in greater numbers on those surfaces which appear to be less brightly illuminated. Gregariousness at settlement is indicated by the distribution of barnacles in isolated groups comprised of numerous crowded individuals, and the presence of populations exclusively within surface fissures of wooden components of bacon assemblies point to rugophilic behaviour in migratory phase cyprid larvae. The importance of some of these reactions in this Cirripede genus is discussed.

Introduction

In an accompanying paper (Skerman, 1958), an account has been given of adult growth in populations of two species of *Lepas, L. anatifera* and *L. australis,* which developed on the underwater surfaces of floating beacons used in offshore hydrographic surveys of two areas of the continental shelf of New Zealand.

In the series of populations of various ages from different localities a number of characteristic trends were noted in regard to the distribution and settlement of both species of barnacles on the beacon surfaces; these features show a resemblance to some aspects of settlement in genera of sessile barnacles which have been in recent years subjects of considerable experimental study. As a result of the wide dispersal of isolated adult populations over the oceans, very few details of this nature are known in *Lepas* species, and as their attachment to beacons provided unique opportunities for examining numerous and extensive settlements it has been thought desirable to record observations that may contribute further knowledge of the biology of this group.

The Surfaces Colonized

Barnacles settled on most underwater surfaces of the beacon assemblies to a depth of 10 ft but there was a notable difference in the density of colonization between various surfaces. The general appearance of a submerged beacon at its equilibrium depth is illustrated. In detail, the supporting float consists of a steel cylindrical drum, flat top and bottom and oval in cross-section with a greatest

diameter of 3 ft and an overall depth of 3 ft 6 in. The lower part of the drum is conical (see Fig. 1). A 20 ft hardwood shaft passes through an open sleeve running longitudinally through the axis of the drum. A light pole bearing flag and radar reflector is lashed to the upper end of the shaft which is maintained in a vertical position by weights at the opposite submerged end. Eye lugs welded to the sides of the float carry mooring lines leading to an anchor.

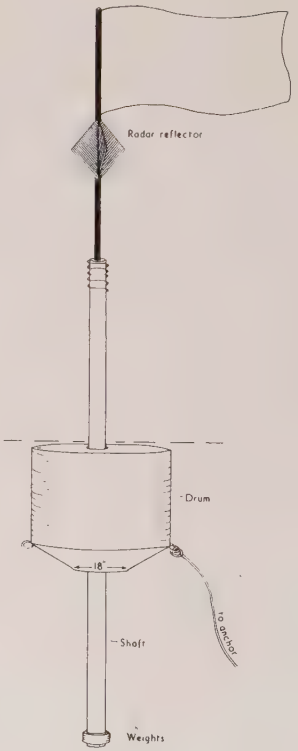

FIG. 1.—Sketch of beacon.

SETTLEMENT

A typical example of the settlement and distribution of barnacles on the surfaces of a beacon after its withdrawal from the sea is shown in Fig. 2.

The greatest density of settlement took place on the lower flat surface of the drum, less intensive colonization occurred on the cone portion, and least on the cylindrical sides and submerged part of the shaft. Whereas almost all available surface on the drum bottom has been colonized, settlement on the cone and sides is distributed either in discreet clumps or aggregates, or is concentrated near surface discontinuities such as the lateral eye lugs and welding seam at the junction of cone and cylinder portions. Settlement on the shaft is confined exclusively within longitudinal splits in the wood. In no case were barnacles found attached to the top of the drum; this surface, however, may not have been submerged continuously.

The concentration of barnacles on the lower surface of the drum suggests that there may have been some distinguishing characteristics of this area to which more barnacle larvae responded by settlement than elsewhere. All surfaces of the steel drum were identical in nature, but in calm weather conditions, varying degrees of turbulence, light intensity, and direction of incident illumination could have arisen about different areas of the drum surface. Under conditions in practice, it is doubtful whether any one area is consistently subjected to more or less mechanical disturbance than others, but even under

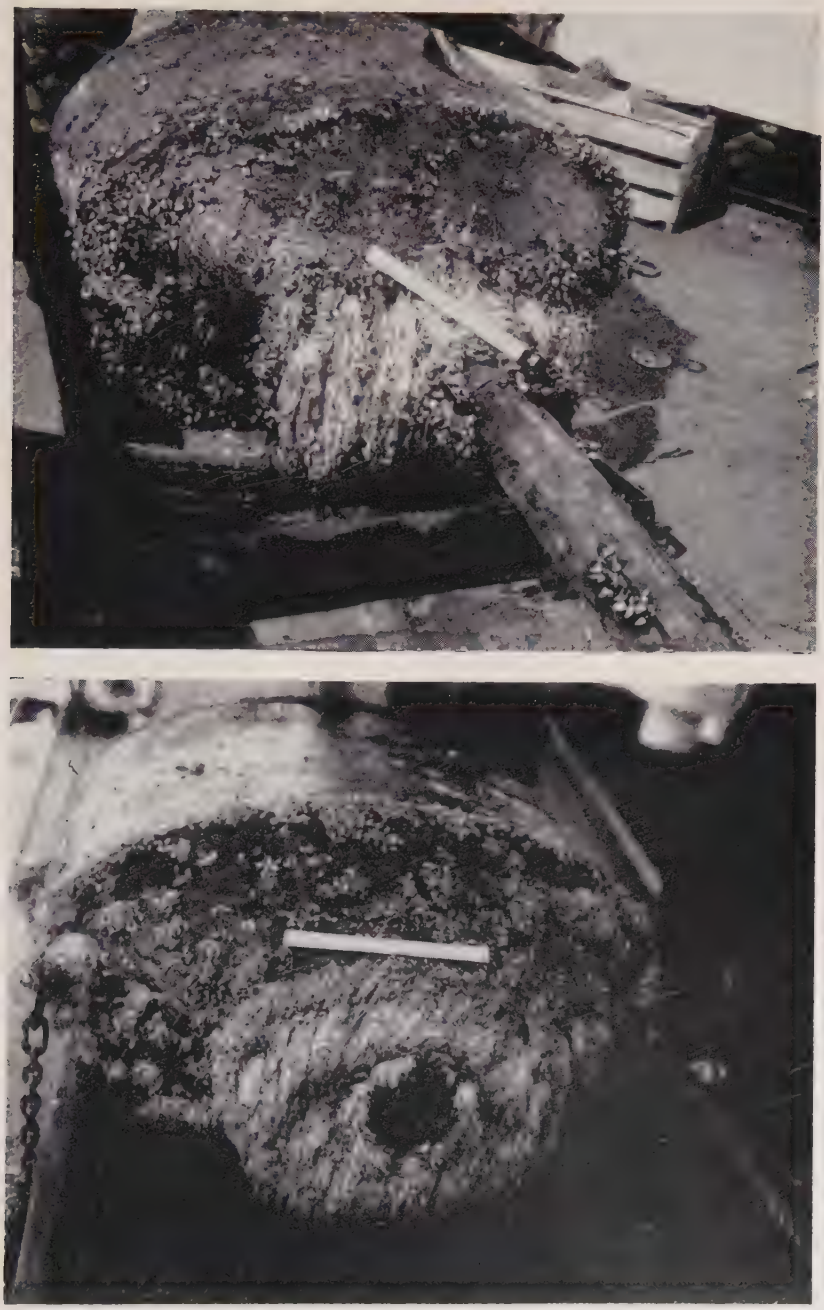

FIG. 2.—Typical examples of *Lepas* settlement on beacon floats and shaft. Both illustrations are of *L. australis* populations from Pegasus Bay. (A foot rule gives the scale.)

the most turbulent of conditions, it is conceivable that lower illumination levels prevail at the bottom-most drum surface, producing a comparatively shaded area.

It is well known that light is an important factor influencing barnacle settlement, and a number of authors have shown that many species tend to attach in greater numbers on experimental surfaces placed in less brightly illuminated areas. Gregg (1945), for instance, noted that in larvae of *Balanus eburneus* there was a greater frequency of attachments on the under sides of horizontal surfaces than on vertical ones, thus confirming the observations of McDougall (1943) and previous authors. In the present instance, therefore, it seems that the high density colonization on the bottoms of beacon drums may have arisen from similar tendencies in *Lepas* larvae to settle on comparatively weakly illuminated surfaces than on more generally illuminated adjacent areas. This discriminatory effect may be considered to represent the aggregate of reactions to light in migratory phase larvae, but there is no clear evidence as to what the precise nature of such reactions might be. It is known that many barnacle species settle on dark-coloured surfaces rather than light ones (Visscher, 1927; Pomerat and Reiner, 1942) and it is difficult to determine whether this is a result of direct attraction, or whether fewer cyprids leave a darker surface after reaching it by random movements (Dr H. Barnes, pers. comm.). Barnes, Crisp, and Powell (1951) have demonstrated that the orientation of the rostro-carinal axis in some intertidal and sublittoral barnacles settled on plane smooth surfaces is largely determined by the direction of incident light, and considered the effect to be a result of light reactions persisting in larvae up till the time of settlement. Later authors (Knight-Jones and Crisp, 1953) regard orientation as resulting from a distinct reaction occurring at the time of settlement. However, Barnes *et al.* (1951) pointed out that positive and negative responses to light (both of which have been observed experimentally) could, in young larval stages have much influence on the dispersion and maintenance of larvae within the appropriate planktonic environment, while in cyprid stages, these responses could tend to bring larvae into the most favourable environments for settlement. That responses of this nature could be of particular significance in *Lepas* larvae will be discussed later.

Whatever the nature of larval reactions involved prior to settlement, the tendency for greater settlements to take place on underneath surfaces, universally shown on all beacons examined, has also been observed in *Lepas* populations on driftwood, planks, etc., found washed up on local beaches. Except where the effect is masked by very dense settlements on small objects, attached barnacles are concentrated on those surfaces which can be recognised as having faced away from the incident light. Another instance of the same trend has been noted in *Lepas australis* populations attached to *Macrocystis* holdfasts which are commonly washed up on south coast beaches of the North Island after

southerly storms in winter. In young populations, the individual barnacles may be found attached exclusively to the inner sides of the haptera forming the network of the holdfast body. In neither of these instances does the possibility of depredation by sea birds of barnacles attached in positions more exposed to the sea surface adequately explain the concentration of populations in the more remote positions. The trend may therefore be of wide occurrence in *Lepas*.

Secondary concentrations of adult barnacles on drum surfaces also appeared about the welding seam between cone and cylinder portions where settlement was commonly observed as an unbroken circumferential band, and also about the lateral eye lugs. It could be suggested that the convexity of the weld seam and projection of the lugs gave rise to shaded areas immeditely beneath them to yield similar conditions with respect to surface illumination as on the bottom of the drum. On the other hand, the experimental work of Crisp and Barnes (1954), and Barnes (1955), has shown that cyprid larvae of a number of Balanomorph species tend to settle in grooves and concavities of an irregular surface, and similar rugophilic behaviour in migrating *Lepas* cyprids could also account for the accumulation of adults in the small grooves present on the irregular surface and on each side of the convex welding seams. That rugophilic behaviour may have played an important part in settlement appears to be clearly shown by the populations upon the beacon shafts (Fig. 2) where the barnacles had settled only within longitudinal splits of the wood.

Another characteristic of *Lepas* settlement on beacon drums was the colonial nature of the distribution of individuals on the generally less densely settled cone and side regions. Barnacles were congregated in isolated groups which ranged in numbers from few to many crowded individuals (Fig. 2) some of which were attached to the peduncles of others. In that considerable areas of free surface, with apparently identical superficial characteristics to those of colonized areas, separated each group of individuals, this crowding cannot have arisen as a result of restriction in space available for settlement. Knight-Jones and Stevenson (1950) observed that cyprids of *Elminius modestus* tend to settle in groups during the initial stages of colonization of surfaces, and from experimental evidence suggested that this may be due to gregarious behaviour of the cyprids prior to settlement. These authors gave instances of gregariousness during settlement in oyster larvae and discussed some general questions of gregariousness in various marine invertebrates. From the results of further experiments, Knight-Jones and Crisp (1953) reported that cyprids are stimulated to settle on contact with barnacles of their own species or with species of the same family, no such appreciable effect arising between different families (Knight-Jones, 1955).

It would appear that the typical aggregations of adult *Lepas* on beacons resemble in character the initial settlement of *Elminius* in groups discussed by these authors. Similar patterns of settlement in

crowded assemblies have previously been observed by Broch (1922) in *Lepas pectinata,* representing further evidence of gregariousness at settlement in another Cirripede family. Having observed epizoic clusters of *Balanus porcatus* da Costa (= *B. balanus* L.) on *Pecten* shells, Barnes (1953) made the suggestion that larval development to the cyprid stage within the mantle cavity, and certain mechanical responses by the newly released cyprids leading to settlement near the parent adult, could account for the formation of these colonial aggregates. Previous records in the literature of colonial aggregations in a number of different species, including *Scalpellum sociabile* Annandale, were discussed with the evidence in several genera for larval incubation up till the cyprid stage. Opposing Barnes' suggestion, Crisp and Knight-Jones (1953) stated that in the few species where incubation of larvae in the mantle cavity were clearly known, there were characteristically few ova, all of which developed directly to the cyprid stage, while the more commonly occurring members of the Thoracic Cirripedes all produce numerous eggs which hatch into free-living planktonic larvae. Aggregation of settled barancles, in the opinion of these authors, was therefore more satisfactory explained as resulting from the behaviour of cyprid larvae prior to attachment.

As aggregations of *Lepas* individuals on beacons were found in young immature populations it is clear that the cyprids must have originated from the plankton, and it therefore seems appropriate to ascribe the colonial nature of settlement to behavioural tendencies of cyprids in the migratory phase. In each group, moreover, it was common to find a few adults conspicuously larger in size than the remainder. These presumably were among the first to colonize the area and may have settled as a result of rugophilic responses to small corrosion pits on the steel surfaces of the drums. By virtue of certain tactile or olfactory responses, as have been proposed to account for gregarious cyprid settlement, later arrivals may have come to establish themselves in the immediate proximity of the initial colonizers.

Discussion

In a group of marine animals where the existence of the adult phase of the life history is patently dependant on the presence of suitable floating objects for settlement, any mechanism, or ability to respond to certain stimuli, that leads to the concentration of freely dispersed larvae towards the sea surface will be of greatly significant survival value. As the overall occurrence of such floating objects must be rare in the oceans (certainly their presence depends on an element of chance) it seems that some reactions in *Lepas* larvae with these effects are implicit as far as perpetuation of the species is concerned. Obviously, this may fully apply to the species *L. fascicularis* in which specialized independent flotation characteristics have evolved in the adult. The

maintenance of cyprids at suitable levels for attachment, which Barnes *et al.* (1951) have suggested may be a function of larval responses to light, would clearly be a particularly valuable effect in *Lepas*. The question of responses by barnacle larvae directly or indirectly to hydrostatic pressure does not appear to have been examined but, if demonstrated, such responses could also be a means by which *Lepas* cyprids maintain themselves in surface layers; furthermore, this factor of the physical environment is not subject to diurnal changes in intensity as is light, and complex alternating diurnal reaction mechanisms are not implied.

After planktonic larvae have reached the cyprid stage of development it is inevitable that they will perish unless a substratum suitable for settlement is encountered within a certain period of time. There is evidence that in other barnacle species settlement of cyprids can be delayed if conditions are unsuitable or if an appropriate substratum is unavailable, and similarly *Lepas* cyprids might prolong their planktonic existence for a limited period. This would afford greater probabilities of cyprids, with the capacity to respond to surfaces by settlement, meeting favourable habitats for adult life; having reached them, any cyprid behaviour, such as rugophily or gregariousness, that may lead to the accumulation and settlement of cyprids within localized areas, will be of indirect advantage to cross-fertilizing hemaphrodite adults.

A striking aspect of the colonization of the Hawke Bay series of beacons by *Lepas anatifera* (Skerman, 1958) was the high rate of settlement that continued throughout the survey period from November to March. In the later months adult populations on some beacons possibly contributed to the production of larvae that may have eventually colonized other beacons in the region, but young newly attached barnacles were as abundant on beacons that had been only a fortnight in the sea as on those immersed for 9 weeks. From size measurements of the largest barnacles in populations from beacons laid the same day over a 20-mile front at an average distance of 30 miles offshore, it appeared that initial settlement must have taken place over the whole area at about the same time. Maintenance of these high rates of settlement so uniformly over the area would have demanded a continuing abundance and wide regional dispersal of larval stock from source populations. It is difficult, however, to balance the extensive colonization of beacons on the one hand, with the scarcity of natural parent populations in the ocean, bearing in mind such hazards of larval life as natural mortality, adequate food supply for feeding nauplii, predation, and probably most important, the lack of available surfaces for settlement at the precise time the cypris stage has been developed.

In this genus of the Cirripedia in which the adult phase of the life history is passed in such a unique manner, larval mechanisms leading to settlement on appropriate surfaces at depths and in positions favourable for the adult animals must be very highly developed.

REFERENCES

BARNES, H., 1953: Orientation and Aggregation in *Balanus balanus* (L.) Da Costa. *J. Anim. Ecol. 22 (1)* : 141-48.

———, 1955: Further Observations on Rugophilic Behaviour in *Balanus balanoides* (L.) *Vidensk. Medd. dansk naturh. Foren. Kbh., 117* : 341-48.

BARNES, H.; CRISP, D. J.; POWELL H. T., 1951: Observations on the Orientation of Some Species of Barnacles. *J. Anim. Ecol. 20 (2)* : 227-41.

BROCH Hj., 1922: Studies on Pacific Cirripedes. Papers from Dr Th. Mortensen's Pacific Expedition 1914-1916. 10 *Vidensk. Medd. dansk naturh. Foren. Kbh. 73* : 215-558.

CRISP, D. J.; KNIGHT-JONES, E. W., 1953: The Mechanism of Aggregation in Barnacle Populations. *J.. Anim. Ecol. 22 (2)* : 360-62.

CRISP, D. J.; BARNES, H., 1954: The Orientation and Distribution of Barnacles at Settlement with Particular Reference to Surface Contour. *Ibid. 23 (1)* . 142-62.

GREGG, JAMES, H., 1945: Background Illumination as a Factor in the Attachment of Barnacle Cyprids. *Biol. Bull. Wood's Hole 88 (1)* : 44-9.

KNIGHT-JONES, E. W.; STEVENSON, J. P., 1950: Gregariousness during Settlement in the Barnacle *Elminius modestus* Darwin. *J. Mar. biol. Ass. U.K. 29* : 281-97.

KNIGHT-JONES, E. W.; CRISP, D. J., 1953: Gregariousness in Barnacles in Relation to the Fouling of Ships and to Anti-fouling Research. *Nature, Lond. 171 (4364)* : 1109-10.

KNIGHT-JONES, E. W., 1955: The Gregarious Setting Reaction of Barnacles as a Measure of Systematic Affinity. *Ibid. 175 (4449)* : 266-7.

MCDOUGALL, K. D., 1943: Sessile Marine Invertebrates at Beaufort, North Carolina. *Ecol. Monogr. 13* : 321-74.

POMERAT, C. M.; REINER, E. R., 1942: The Influence of Surface Angle and of Light on the Attachment of Barnacles and Other Sedentary Organisms. *Biol. Bull. Wood's Hole 82* : 14-25.

SKERMAN, T. M., 1958: Rates of Growth in Two Species of *Lepas* (Cirripedia). *N.Z. J. Sci. 1* : 402-11.

VISSCHER, J. P., 1927: Nature and Extent of Fouling of Ships' Bottoms. *Bull. U.S. Bur. Fish 43 (2)* : 193-252.

THE SUSPENDED PLUMMET METHOD FOR DENSITY MEASUREMENTS

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Summary

An apparatus is described for measuring densities by a suspended plummet method. Applied to sea water, the densities of samples can be determined with an accuracy of 2×10^{-5}g.ml.$^{-1}$ at the rate of sixty per day.

Introduction

Different types of ocean water can be distinguished by their salinities and temperatures. A knowledge of these properties is therefore an aid in tracing the movements of the various water masses. Work at this Institute provides a large number of samples every year for salinity analysis. The apparatus to be described was assembled for analysis of these samples.

The basis of the method is comparison of the buoyancies of a plummet in distilled water and in a sea-water sample. The density of both distilled water and sea water varies with the temperature, which must therefore be measured. With this information the density of a sample at the measured temperature can be found. From Knudsen's tables (Knudsen, 1901) the value that would be found for the density at 0° C can be deduced. The salinity, which is directly related to the density at 0° C, is also given by Knudsen's tables.

The method has long been recognized as a simple means of obtaining fairly accurate salinity values (e.g., Thompson, 1932; Cummings, 1932), but it has not been very widely used for analysis of ocean water. For oceanographic work an accuracy of 0·02‰ in the salinity is desirable, and chemical analysis for the chloride content has been favoured as a more practical method of obtaining this accuracy in salinity determinations. Both Thompson and Cummings discuss sources of error in the plummet method.

The recent introduction of chemical balances of the single-pan type in which the weighings are made by a substitution method and the weights handled semi-automatically, now allows accurate weighings to be made quickly. This greatly reduces the work involved in using a suspended plummet method for salinity determinations. The plummet method was chosen as a simple method with which relatively unskilled operators could handle large numbers of samples and obtain salinity

values not greatly inferior in accuracy to those usually obtained by the chemical method.

The accuracy of the density determinations is approximately 2×10^{-5}g.ml.$^{-1}$ which corresponds to an error in the salinity of approximately 0·03‰. An operator can deal with about sixty samples a day.

DESCRIPTION OF THE APPARATUS

The apparatus is described with reference to Figs 1 and 2. These show a hollow silica plummet, weighted with mercury, suspended by a fine tungsten wire (diameter $2{\cdot}5 \times 10^{-3}$cm) from a Mettler balance which can weigh masses of up to 200g with an accuracy of $\pm$ 0·1mg.

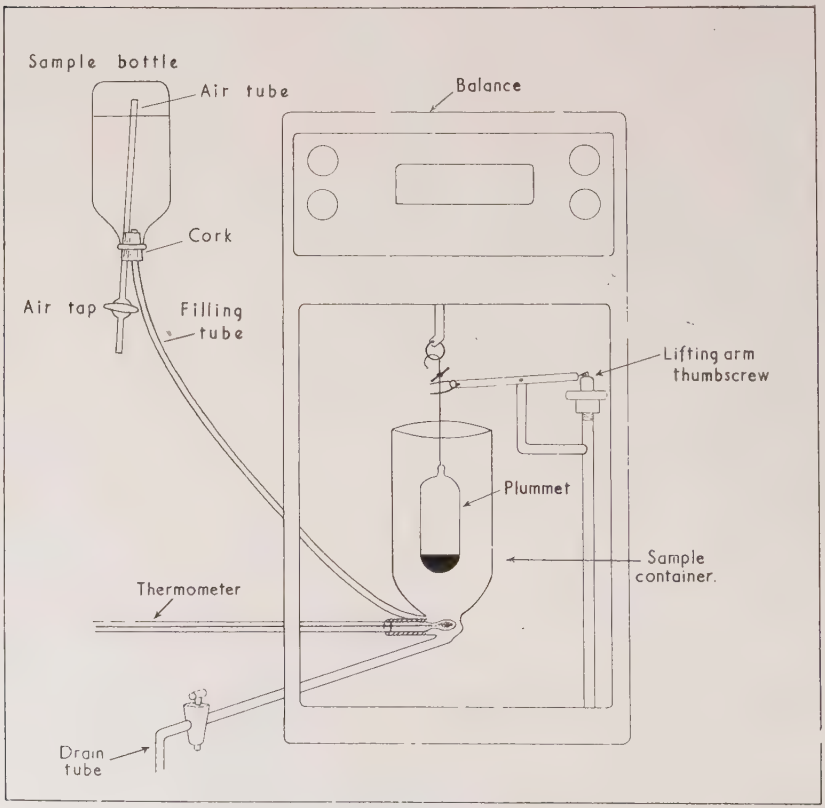

FIG. 1.—Diagram showing the main parts of the apparatus.

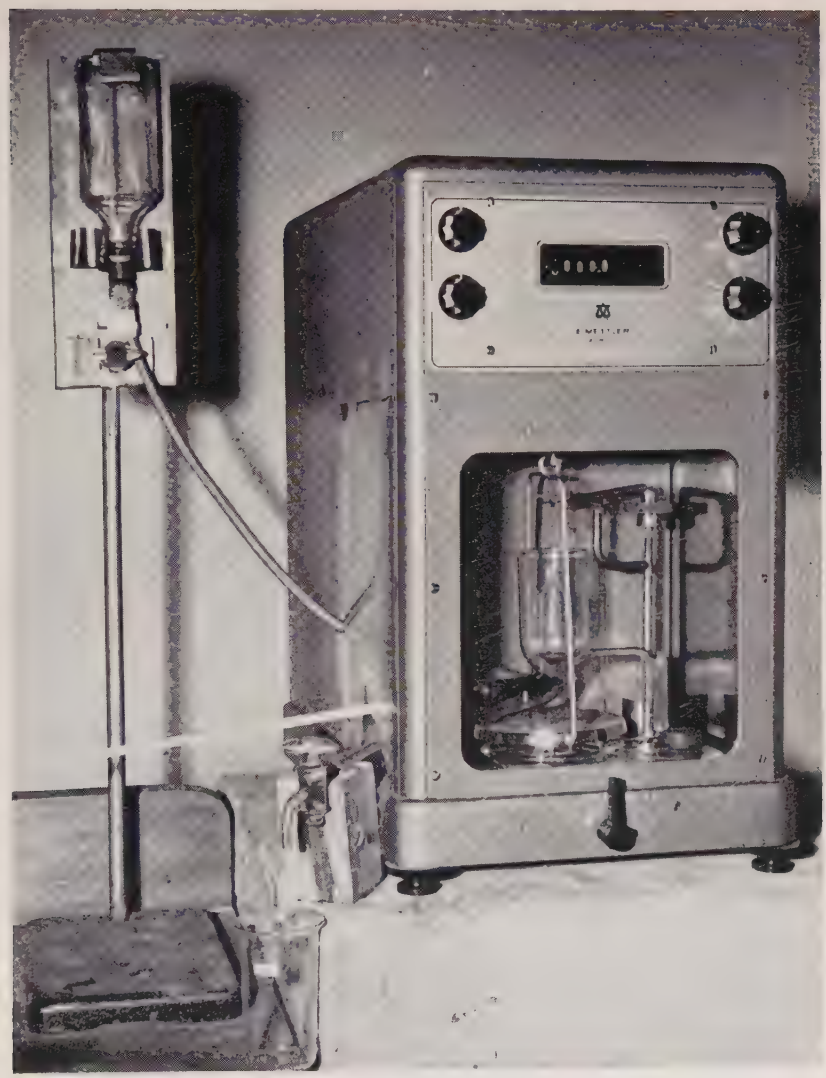

FIG. 2.—General view of the apparatus.
—Photograph, E. J. Thornley, D.S.I.R.

In the present apparatus the plummet weighs approximately 26·5g (W_a), 4·8g (W_w), and 4·2g (W_s) in air, distilled water, and sea water respectively. The plummet volume is therefore approximately 21·7ml. A lever is provided with which the load can be taken off the balance to check the zero, which changes slightly with ambient conditions.

The plummet is surrounded by a container which requires 100ml of fluid to fill it when the plummet is immersed. This container is filled by gravity flow from a 4oz sample bottle. The flow is controlled by an air tap. If bubbles are formed and cling to the plummet, the measurement will be spoiled. Other filling systems are possible, but this is a convenient method for transferring fluid from the sample bottle to the container at a reasonable speed and without forming bubbles on the plummet. The container is drained by a gravity drain tube.

Weighings must be made with the plummet immersed in distilled water or sea water of known temperature. A thermometer with bulb exposed to the fluid is used to read the temperature to the nearest 0·05° C.

Care was taken never to allow the plummet to dry after immersion in salt water without first washing it. The apparatus was washed by filling the container with liquid detergent solution and rinsing several times with fresh and distilled water. If the plummet was visibly dirty it was removed from the apparatus for more rigorous cleaning. To help keep the plummet clean, and to aid in draining the water from the container, the surfaces of the plummet and container were siliconed. A single application of "Desicote" gave a permanent silicone layer on the surfaces.

The routine for a series of measurements was as follows. Three measurements of W_w (the weight of the plummet in distilled water) were made, and the temperature of the water measured at each weighing. As a quick check on the apparatus the values of W_w were plotted against the associated temperature values to see that the results were consistent with each other and with previous measurements. Measurements of W_s (weight of the plummet in a sea-water sample) and sample temperature were then made for thirty samples. Three more measurements of W_w and associated temperatures were then made after the apparatus had been thoroughly rinsed to remove traces of salt water. It was not necessary to make the weighing of the plummet in air a routine measurement.

The sample densities at the temperature of measurement were calculated from equation (6). The densities at 0 ° C and the salinities could then be found with the aid of Knudsen's tables. (Knudsen, 1901).

Equations For Density

Density is numerically equal to the ratio of mass to unit volume, the unit of volume being the litre, defined as that volume of pure water at 3·98° C which has the same mass as the standard kilogramme. Thus, the density of a sample of liquid at t° C is given by

$$\text{Density (g.ml.}^{-1}) = \frac{\text{Mass of volume of the sample at } t^\circ \text{ C}}{\text{Mass of an equal volume of water at } 3{\cdot}98^\circ \text{ C}} \times \frac{(1000\text{g})}{(1000\text{ml})} .$$

If the plummet is weighed in the three fluids air, water, and sample, the equations (1), (2), and (3) express the mass equalities found.

$$m - V\sigma_a = W_a - W_a \times (\sigma_a/\triangle) \quad \ldots\ldots\ldots (1)$$

$$m - Vd_t = W_w - W_w \times (\sigma_w/\triangle) \quad \ldots\ldots\ldots (2)$$

$$m - V\rho_t = W_s - W_s \times (\sigma_s/\triangle) \quad \ldots\ldots\ldots (3)$$

Here the subscripts a, w, and s refer to air, water, and sample respectively, and

m = mass of the plummet,

W = a balance weight value (e.g., W_s = balance reading when the plummet is weighed in a sample),

σ = air density (e.g., σ_a = air density during a weighing of the plummet in air),

d_t = water density at t° C,

ρ_t = density of the sample at t° C,

$\triangle$ = density of balance weights,

V = volume of the plummet,

From (1) and (2), we get

$$V = \frac{W_a - W_w - W_a \times (\sigma_a/\triangle) + W_w \times (\sigma_w/\triangle)}{d_t - \sigma_a} \quad \ldots\ldots\ldots (4)$$

and from (1), (2), and (3)

$$\rho_t = \frac{(W_a - W_s - W_a \times (\sigma_a/\triangle) + W_s \times (\sigma_s/\triangle))}{V} + \sigma_a \quad \ldots\ldots\ldots (5)$$

For the purposes of discussing errors in ρ_t the values for W_a, W_w, and W_s given above will be used. From (5) it can be shown that errors in W_s and W_w are more critical than errors in W_a. An error of 1mg in W_a leads to an error of $1{\cdot}3 \times 10^{-6}$g.ml.$^{-1}$ in ρ_t. An error of 0·1mg in W_s causes an error of $4{\cdot}6 \times 10^{-6}$g.ml.$^{-1}$ in ρ_t. A change of $4{\cdot}6 \times 10^{-6}$g.ml.$^{-1}$ in the density is equivalent to a change of approximately 0·0057‰ in the salinity of sea water. These figures can be referred to in gauging the importance of some of the error sources discussed below.

The Effect of Air Density

This is discussed with a view to simplifying equation (5). Measurements of W_w are made before and after measurements of W_s, and hence σ_w and σ_s are approximately equal to each other, whereas W_a may be measured in a different day so that σ_a could have a value rather different from either σ_w or σ_s. By assuming that $\sigma_w = \sigma_s$, and considering the maximum error likely to be caused by this assumption because of changes of air density during a series of measurements, it can be shown that for density measurements to an accuracy of 1×10^{-5}g.ml.$^{-1}$ the maximum error is negligible. Similarly, by putting $\sigma_a = \sigma_w\ (= \sigma_s)$ and considering the errors caused by the expected differences between σ_a and $\sigma_w\ (= \sigma_s)$ it can be shown that to the accuracy required the error is again negligible.

Putting $\sigma_a = \sigma_w = \sigma_s$ in equation (5) we obtain

$$\rho_t = \frac{(W_a - W_s)\, d_t}{(W_a - W_w)} + \sigma_a \left(1 - \frac{(W_a - W_s)}{(W_a - W_w)}\right) \qquad \text{.....(6)}$$

For sea water samples $(W_a - W_s)/(W_a - W_w)$ is approximately equal to 1·025, so that the last term in (6) is small and may be regarded as constant. The value of W_a is not as critical as the values of W_s or W_w. In practice a new value for W_a was only necessary after a replacement of the suspension wire. Equation (6) makes the calculation of ρ_t from the experimental data fairly easy.

The accuracy of equation (6) is greatest when W_s and W_w are small, i.e., the plummet should ideally be slightly denser than the densest sea water sample likely to be encountered.

The Effect of Surface Tension

By direct measurement it was found that the tungsten suspension wire of diameter $2{\cdot}5 \times 10^{-3}$cm was pulled by a surface tension force of 0·3mg when dipped vertically into pure or sea water. The standard deviation of a series of measurements was approximately 0·1mg, and

individual deviations could be as large as 0·2mg. Variations in surface tension effects are therefore one of the larger sources of error. If the surface tension force contributions to W_s and W_w are small and equal, then, by substituting numerical values in equation (6) it can be seen that they may be ignored.

TEMPERATURE EFFECTS ON THE DENSITY

A 0·1° C rise in the temperature decreases the densities of sea and pure water at room temperatures by approximately $(2{\cdot}5 \pm 0{\cdot}5) \times 10^{-5}$g.ml.$^{-1}$ and $(2{\cdot}0 \pm 0{\cdot}5) \times 10^{-5}$g.ml.$^{-1}$ respectively. These figures show the importance of reading the thermometer accurately.

An error in the calibration of the thermometer involves an error in ρ_t. An approximate expression for ρ_t is $\rho_t = \rho_o \times \varphi(t) \simeq ((W_a - W_s) \times d_t)/(W_a - W_w) = ((W_a - W_s) \times d_o \times f(t))/(W_a - W_w)$, where ρ_o and d_o are sea and pure water densities at 0° C, and $\varphi(t)$ and $f(t)$ are functions of temperature. All these quantities, except ρ_o, have values close to unity, and therefore the rate of change of the calculated value of ρ_o with calibration error is given by

$$\partial\rho_o/\partial t \simeq \rho_o(f'(t) - \varphi'(t)) \quad .$$

The value of $\partial\rho_o/\partial t$ for a temperature in the room temperature range of 15° to 25° C is $-(6 \pm 1) \times 10^{-5}$g.ml.$^{-1}$ ° C^{-1}.

To reduce temperature changes occurring during measurements, the samples were left in the balance room overnight to approach room temperature. Temperature effects were one of the major sources of error, although they could have been reduced somewhat by more accurate measurement.

BIOCHEMICAL CHANGES AND SOLUTION OF GLASS

Under some conditions, biochemical changes in sea water and the solubility of glass in water can lead to considerable errors in the determination of salinities from density measurements (Thompson, 1932). The magnitudes of these storage errors have not been specifically investigated with the present apparatus, although a number of identical samples of sea water scattered unknown to the operator through a series of ordinary samples, and which were analysed over a period of several weeks, gave no indication that the sources of error under discussion were of much importance.

FORMATION OF BUBBLES ON THE PLUMMET

The filling system must be carefully adjusted so that bubbles are not formed and left on the plummet. With reasonable care the errors caused by bubbles can be kept below significant levels (unless the sample happens to be releasing gas dissolved under pressure).

ERRORS IN WEIGHING

The vernier scale gives a reading to the nearest 0·1mg and the accuracy claimed for the balance is ± 0·1mg. Errors in W_s and W_w are more important than errors in W_a, and the errors in the values of W_s will be larger than the errors in W_w because several measurements of the latter are made and an average value is used.

PLUMMET VOLUME CHANGES

Hereafter, the value of the expression $(W_a - W_w)/d_t$ in equation (6), from which sample densities are calculated, will be referred to as the plummet volume, although the exact value for the volume is given by (4), an equation involving air densities. When several measurements of the plummet volume were made over a short period of time, the standard deviation of the results was usually found to be approximately equal to 5×10^{-6} of V. Occasionally the standard deviation would be as large as 1×10^{-5} of V. The measured plummet volume would be expected to change slightly from day to day because of changing air conditions, but allowing for this it was found that the plummet volume, as determined from the average of several measurements, varied significantly from day to day for no apparent reason. The changes could be in either sense. Several runs were made in which the volume was measured before and after making measurements on thirty samples of sea water which had been stored for a month and had visible particles of matter in suspension. Some significant changes were found but none larger than 1×10^{-5} of V. The average change was approximately 5×10^{-6} of V. Over a period of several days, variations from a mean value of 2×10^{-5} of V were sometimes observed. Because of these observations, while doing routine measurements on sea water the volume of the plummet was redetermined after measurements had been made on thirty samples.

It is difficult to ascribe the changes to other than real effects. Thompson (1932) states that the formation of a film on the plummet appears to be the chief source of error in the determination of salinities from densities. The effects noted above tend to confirm this opinion.

OTHER SOURCES OF ERROR

Although the expansion of the fused silica plummet with temperature is small, it is not negligible. The volume coefficient of expansion for fused silica is approximately 1×10^{-6} per ° C. Since the plummet volume was determined daily, the value found refers to a room temperature close to that at which the sample densities were measured, and no correction need be made for the plummet expansion under these circumstances.

Other sources of error which have been considered but are regarded as negligible in the present case (density measurements made with an accuracy of the order of 1 part in 10^5) are as follows: evaporation of the sample during a measurement, density variations of plummet and samples caused by compressibility effects, impurities in the distilled water (including dissolved air, see for example, Kirshenbaum (1951), variations in the length of suspension wire immersed and the slight contamination of each sample with the preceding one caused by imperfect drainage of the sample container. Because the plummet and balance weights are earthed when the sample container is filled and the balance is in the rest position, the effects of electrostatic attraction are unimportant.

PERFORMANCE OF THE APPARATUS

Errors that affect the density results may be divided into three classes: constant errors, slowly changing errors, and errors that change at random with each measurement. Each source of error may contribute to one or more of these classes, but generally each source contributes mainly to only one class.

The main contributions to the constant error would be expected to come from the error in the thermometer zero, and errors in the calibration of the small-value balance weights. The constant error could best be found by making repeated measurements on a single sample of sea water whose density was already known accurately from other measurements. Before a thermometer was used the zero error was checked and the small-value balance weights were checked against each other for consistency when the balance was set up. From a consideration of these measurements and the other possible sources of constant errors, it is concluded that the total constant error should be less than 5×10^{-6}g.ml.$^{-1}$.

Any slowly changing error will arise chiefly as a result of variations of the plummet volume. From the nature of the other possible error sources in this class and from the results quoted above for variations of the plummet volume, the total slowly changing error is expected to be approximately equal to 5×10^{-6}g.ml.$^{-1}$.

The random error, which comes chiefly from temperature measurement errors, surface tension variations, and weighing errors, can be measured by making several short series of measurements on single samples. The value found for the standard deviation from such measurements was in most cases approximately equal to 5×10^{-6}g.ml.$^{-1}$, although it was as large as 1×10^{-5}g.ml.$^{-1}$ on some occasions.

Altogether, density results may be expected to have an absolute error of 1×10^{-5}g.ml.$^{-1}$ with a superimposed random error of 1×10^{-5} g.ml.$^{-1}$ (standard deviation). In terms of salinity, the errors quoted for density imply that most of the salinity values would differ from the

true salinity values by less than 0·03‰. These figures for expected accuracy are in fairly general agreement with those quoted by Cummings (1932).

A weighing of the plummet in a sample could be made in less than three minutes, and for sea water the densities at 0° C, and the salinities, could be found with the aid of a computing machine, and interpolation tables for linear interpolations between the values given in Knudsen's (1901) tables, at the rate of thirty per hour. Time must be allowed for washing the plummet and making determinations of the plummet volume. Also, occasional breakages of the suspension wire must be expected. An average of about sixty salinity determinations per day can be done by an operator.

The method is therefore fairly quick, and yet is accurate enough to be useful in some phases of oceanography. It has the advantage of being a simple method in which a direct comparison is made with the density of distilled water, a stable and readily procurable standard. For special purposes, such as calibrating other instruments, an accuracy of 1×10^{-5}g.ml.$^{-1}$ would be obtainable by making repeated measurements on samples to reduce random errors in the results.

CRITERIA FOR THE DESIGN OF A SUSPENDED PLUMMET

(1) The plummet should be made from fused silica to reduce temperature-expansion effects.
(2) The suspension wire should be as fine as possible, consistent with a reasonable working life for the suspension. Fine tungsten wire is one of the strongest materials available. (See, for example, Liebhafsky, *et al.*, 1947).
(3) To reduce volume-change errors, the plummet should have smooth contours and be easily accessible for cleaning.
(4) In general, the plummet volume should be large, although this is controlled by various factors, e.g., the nature of the balance to be used and the sample size available.
(5) The plummet should be of robust structure in order that it may have a small compressibility.
(6) The plummet density should be only slightly greater than the densities of the liquids to be tested so that air density variation effects are reduced. However, the difference in densities should not be so small that the plummet moves sluggishly in the test liquid, causing the balance to creep to the equilibrium position.

IMPROVEMENT OF ACCURACY

The accuracy could be improved by giving more attention to the major sources of error such as temperature measurement and control, weighing errors, surface tension effect, and plummet volume changes. Measurement of densities to an accuracy of, say, 1×10^{-6}g.ml.$^{-1}$ (an

accuracy which has been obtained for heavy water samples using plummets) would require a much more complex apparatus which would be much slower in use. For sea water, difficulties with plummet volume changes would probably be the hardest to overcome. It would almost certainly be easier to use some form of free-swimming plummet, rather than a suspended plummet because the latter is affected by surface tension forces which are very variable unless the liquid surface is extremely clean. Kirshenbaum (1951) refers to most of the different forms of free-swimming plummet that have been used. Each of the papers by Rochford *et al.* (1955) and Groth *et al.* (1952) refers to an additional type.

For sea water, it is doubtful whether it would be worth while making density determinations with an accuracy of 1×10^{-6}g.ml.$^{-1}$ unless the measurements were made soon after the samples had been collected. Direct density determinations always involve force measurements and are therefore difficult to do accurately at sea because of the forces introduced by ship movement. In the past, measurement of the chloride content has been the most favoured method for the routine analysis of sea water. Similarly, the future of routine analysis appears to lie in the development of apparatus which measures some quantity which depends on the salt content; the density, when required, can be found from previously measured relationships between salt content and density.

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REFERENCES

CUMMINGS, N. W., 1932: A Sinker Method for the Determination of Specific Gravities. *Scripps Inst. Oceanogr., tech. Bull. 3* : 101-18.

GROTH, K.; HELLSTEN, M.; SANDEGREN, E., 1953: A New Hydrostatic Balance with Magnetically Suspended Float, *in* "Transactions of the Instrument Measuring Conference". The Swedish Association of Engineers and Architects, Stockholm.

KIRSHENBAUM, I., 1951: "Physical Properties and Analysis of Heavy Water." McGraw Hill, New York.

KNUDSEN, M., 1901: "Hydrographic Tables". Gad, Copenhagen.

LIEBHAFSKY, H. A.; BRONK, L. B.; BALIS, E. W., 1947: Fine Tungsten Wire in the Laboratory. *Rev. sci. Instrum. 18* : 854.

ROCHFORD, D. J.; JITTS, H.; PROCTOR, A., 1955: The Chainomatic Pycnometer: An Instrument for the Rapid Determination of the Salinity of Sea Water. *Aust. J. Mar. Freshw. Res. 6* : (1), 66.

THOMPSON, T. G., 1932: The Physical Properties of Sea Water, *in* Physics of the Earth, 5 (Oceanography). *Nat. Res. Coun. Wash. Bull. 85* : 63-94.

RATES OF GROWTH IN TWO SPECIES OF *LEPAS* (Cirripedia)

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Summary

Rates of adult growth after settlement are outlined for two species, *Lepas anatifera* L. var. *testudinata* Aur. and *L. australis* Darwin, populations of which colonized floating beacons used in coastal hydrographic surveys. Slower growth was noted in *L. australis,* which attached to beacons in Pegasus Bay, than in *L. anatifera,* a larger form which appeared in more northern and warmer waters of Hawke Bay. In both species, capitulum growth appeared to be retarded and peduncle growth accelerated in crowded populations that developed on certain surfaces.

Ovigerous lamellae appeared in the mantle cavities of *L. anatifera* individuals with a least capitulum length of 23 mm, 4 to 5 weeks after settlement, with nauplii hatching after the fifth week from barnacles 27 mm in capitulum length. No mature *L. australis* adults were present in populations of a maximum age of 6 weeks (18·0 mm in size), but at 8 weeks (21·0 mm) nauplii were being shed by many individuals. The evidence suggested that in each species there may be a considerable variation in size between barnacles attaining maturity.

Introduction

Although historically one of the most familiar of marine animal groups, there is little information on growth rates in pedunculate barnacles of the genus *Lepas* L. Oceanic in their occurrence, pelagic and usually attached to widely dispersed floating objects in their mode of adult life, *Lepas* species are for the most part known from their appearances on material found by chance either drifting in the seas or washed up on the coasts, and there is seldom any certainty as to when, or even in what areas, these populations initially arose.

Opportunities of making some regular observations on this group of barnacles arose during hydrographic surveys in New Zealand coastal waters made from H.M.N.Z.S. *Lachlan,* of the Royal New Zealand Navy. In these operations it is occasionally necessary to establish floating beacons which, anchored at certain geographical positions, serve as supplementary visual survey marks. After a period of time in the water, many of these beacons have been found to bear extensive *Lepas* populations, and, since both the duration of immersion of each beacon and its exact position are known, information about barnacle populations of differing ages from different coastal regions has accumulated.

The present data have arisen from two hydrographic surveys off the east coast of New Zealand, one made during the autumn and spring of 1952 near Pegasus Bay, South Island, and the other during the summer

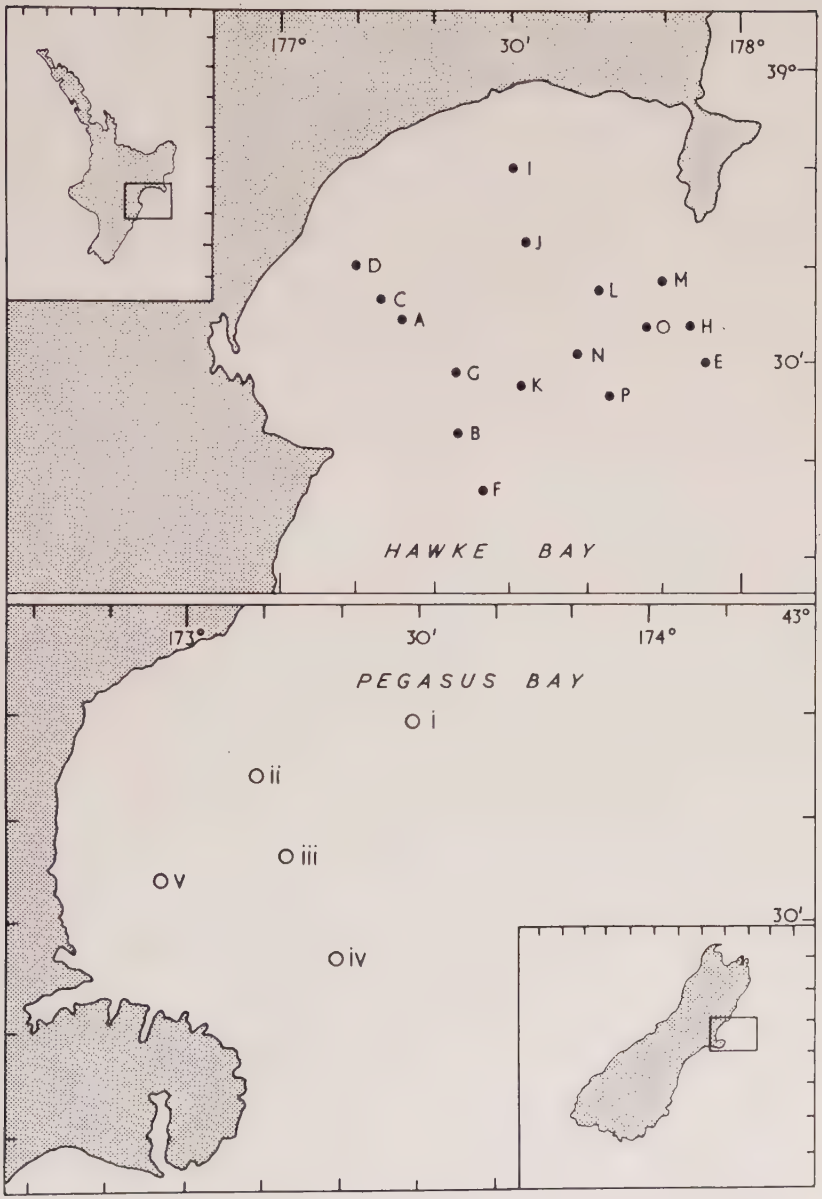

FIG. 1.—Chart showing the distribution of survey beacons on which *Lepas* populations developed in Hawke Bay and Pegasus Bay.

of 1954–55 near Hawke Bay, North Island. These localities, and the positions at which beacons were laid are shown in Fig. 1. Two species

of barnacles colonized the surfaces of beacons in these areas, *Lepas anatifera* Linnaeus var. *testudinata* Aurivillius in Hawke Bay, and *L. australis* Darwin in Pegasus Bay.

COLLECTIONS

An assembled survey beacon (Skerman, 1958, fig. 1) consists of a water-tight steel drum which supports a hardwood shaft, 20 ft long and 6 inches in diameter, fixed so that the drum lies about 12 ft from one end. When in position, the drum floats just below the sea surface and the shaft is vertical, the upper end bearing a staff with flag or radar reflector and the submerged part carrying ballast weights. Mooring lines are attached to the drum. Stalked barnacles were found to settle predominantly on the surfaces of the drum, but attachment also took place on the submerged part of the shaft.

After removal of a beacon from the sea, samples of the attached barnacle populations were taken at random from all surfaces of the drum and shaft as soon as the assembly was secured inboard. In some cases, selective sampling was made from different areas, such as the sides and bottom of the drum and shaft, in order to determine any differences in growth and settlement between populations on the various surfaces. Measurements of capitulum and peduncle dimensions were taken, and specimens were preserved in formalin. A number of peduncle measurements of live animals were made before they were detached from the surfaces.

GROWTH

Darwin (1851) commented that all Cirripedes grow rapidly; most investigations of this aspect, however, have concerned sessile intertidal and sublittoral species which are accessible for regular observation. Data previously published in the literature on rates of growth in adult *Lepas* are summarized on the opposite page.

In view of the extreme variability of the size of the peduncle in *Lepas* (Darwin, 1851), size measurements based on this feature alone become unreliable, and for this reason most authors have considered the capitulum dimensions to be a more conservative index of size. For the present purposes, length of capitulum (from basal scutal angle to apex of the tergum) has been used.

As the immersion period of each beacon also represents the maximum possible age of the adult barnacles attached to its surfaces, some indication of growth rates in the two species is given by comparison of the sizes of the largest barnacles from different beacons which had been in the sea for differing periods of time. These details are set out in

Species	Substratum	Locality	Max. age	Largest size (mm)					Authority
				Capitulum			Peduncle		
				length	breadth	width	length	diameter	
L. anserifera	Keel of s.s. *Siboga*	East Indies	40 d	21	—	—	—	—	Hoek (1907)
L. anserifera	Keel of s.s. *Siboga*	East Indies	107 d	25	—	—	—	—	Hoek (1907)
L. anserifera	Buoy	Ganjam Coast (East India)	4 w	8	—	—	—	—	Annandale (1909)
L. anatifera	Well	Japan	1 m	(1) 11·5 (2) 14·0	7·0 10·0		6·0 6·0	1·5 3·5	Broch (1922)
L. anatifera	Ship	Roscoff-Spain	113 d	33·0	22·0	8·0	—	—	Gruvel, quoted by Kruger (1940), p. 328
L. anatifera			1 m	14·0	—	—	—	—	Stephensen (1933) quoted by Boetius (1952–3)
L. anatifera	Ship	Brazil-England	11 w	—	18·0	—	55·0	—	Orton (1930)
L. anatifera	Buoy	Avachinskoj Bay	2 m	25·0	15·0	—	25·0	6·0	Tarasov & Zevina (1957)
L. pectinata behringiana	Buoy	Avachinskoj Bay	2 m	22·0	—	—	6·0	—	Tarasov & Zevina (1957)
L. hillii	Ship	England-Australia	5 m	27·0	16·0	—	22·0	—	Orton (1930)
L. hillii	Ship	Brazil-England	11 w	—	20·0	—	60·0	—	Orton (1930)

d = days w = weeks m = months

TABLE 1.—Sizes of the Largest Barnacles from Populations of *Lepas anatifera* and *L. australis* taken from Survey Beacons Submerged for Different Periods of Time.

Beacon	Position		Set	Recovered	Days submerged	Range of sea surface temperatures (° C)	Size of largest barnacles (length of capitulum in mm)
Lepas anatifera var. *testudinata*							
A	177° 16·5′ E	39° 25·0′ S	3/11/54	16/11/54	14	16·7 (mean)	5·5
B	177° 22·5′ E	39° 37·5′ S	3/11/54	16/11/54	14	16·7 (mean)	6·0
C	177° 13·0′ E	39° 23·0′ S	3/11/54	16/11/54	14	16·7 (mean)	5·0
D	177° 10·0′ E	39° 20·0′ S	3/11/54	16/11/54	14	16·7 (mean)	5·5
E	177° 55·0′ E	39° 30·0′ S	16/11/54	30/11/54	14	16·7 to 17·2	9·0
F	177° 26·3′ E	39° 43·5′ S	16/11/54	30/11/54	14	16·7 to 17·2	10·0
G	177° 22·0′ E	39° 31·0′ S	3/11/54	30/11/54	26	16·7 to 17·2	11·0
H	177° 53·0′ E	39° 26·0′ S	26/ 1/55	23/ 2/55	29	19·4 to 20·0	16·0
I	177° 30·0′ E	39° 10·0′ S	19/ 1/55	25/ 2/55	37	19·4 to 20·0	27·0
J	177° 31·0′ E	39° 17·0′ S	19/ 1/55	27/ 2/55	39	19·4 to 20·0	28·0
K	177° 31·0′ E	39° 32·0′ S	19/ 1/55	1/ 3/55	41	19·4 to 18·8	21·5
L	177° 42·0′ E	39° 22·0′ S	19/ 1/55	7/ 3/55	48	19·4 to 18·8	29·0
M	177° 50·0′ E	39° 21·0′ S	19/ 1/55	7/ 3/55	48	19·4 to 18·8	35·0
N	177° 38·0′ E	39° 29·0′ S	19/ 1/55	22/ 3/55	63	19·4 to 18·3	29·0
O	177° 47·0′ E	39° 26·0′ S	19/ 1/55	22/ 3/55	63	19·4 to 18·3	39·0
P	177° 43·0′ E	39° 33·0′ S	19/ 1/55	22/ 3/55	63	19·4 to 18·3	28·0
Lepas australis							
i	173° 28·4′ E	43° 10·6′ S	11/11/52	9/12/52	28	12·5 to 15·5	12·0
ii	173° 7·5′ E	43° 16·0′ S	20/ 3/52	24/ 4/52	35	13·6 to 12·0	15·0
iii	173° 12·2′ E	43° 23·1′ S	20/ 3/52	24/ 4/52	35	13·6 to 12·0	17·0
iv	173° 19·5′ E	43° 32·8′ S	30/10/52	10/12/52	41	11·1 to 15·5	18·0
v	172° 56·7′ E	43° 25·2′ S	29/ 1/52	26/ 3/52	56	13·6 to 15·8	28·0

Table 1. A limited amount of sea surface temperature data for both regions was provided by ship thermograph records, and these have been included in the table to indicate major temperature differences which may have had some influence on growth during different periods.

Although the data from beacons offer some advance in knowledge of growth rates in the two species concerned, its approximate nature must be emphasized in that no account can be taken of the range of variability in growth rates among individuals of a population, and that the maximum age, here taken as the overall period of immersion of each beacon, may exceed the interval of time elapsed between initial settlement of the cypris larvae and the recovery of the beacon. For instance, some discrepancy in size is apparent in the Hawke Bay series of beacons *A* to *F*, all of which were immersed 14 days. The largest *L. anatifera* barnacles on beacons *E* and *F* were nearly twice the size of those on *A*, *B*, *C*, and *D*. The *A* to *D* group was in the sea during the fortnight preceding the immersion period of *E* and *F*, and it seems that larval settlement on the former group may have been delayed until some time after they were set in the sea, whereas settlement on *E* and *F* may have occurred soon after immersion. It will be seen from Fig. 1 that beacons *A*, *B*, *C*, and *D* were all closer inshore than *E* and *F*, and it is possible that temporary changes in wind and current systems may have affected the dispersion of the pelagic larvae. Similarities in maximum size between barnacles suggest that colonization began on each beacon from the same group about the same time, and the extensive area over which beacons were placed point to a relatively wide distribution of larval stock.

Maximum size and maximum age data from the series have been plotted in Fig. 2 for each species. While the maximum growth curve for *L. anatifera* indicates a higher rate of growth in this species than in *L. australis*, it will be noted from Table 1 that sea surface temperatures prevailing in Pegasus Bay during the growth period were lower than in Hawke Bay and may have contributed to slower growth in the *L. australis* populations. The maximum growth rate curve drawn for *L. anatifera* suggests a relatively increased rate of growth between the points corresponding to maximum ages of 30 and 42 days. However, as shown in Table 1, immersion of beacons *H*, *I*, and *J* took place during the summer months between January and March; higher sea temperatures during this period may be expected to have accelerated the growth of the attached barnacles to a higher rate than that prevailing during the late spring months of November and December.

Lack of detailed information in the literature leaves some doubt as to the maximum size to which *L. anatifera* var. *testudinata* may grow. This form was first described as a separate species, *L. testudinata* by Aurivillius (1892), but was subsequently considered by Nilsson-Cantell (1928) to be a variety of *L. anatifera* Linn. 1767, synonymous with *L. anatifera* var. *c.* of Jennings (1915) and *L. affinis* of Borradaile (1916). The size of the largest individual specimen mentioned by these authors was one of unknown age with length of capitulum 22 mm,

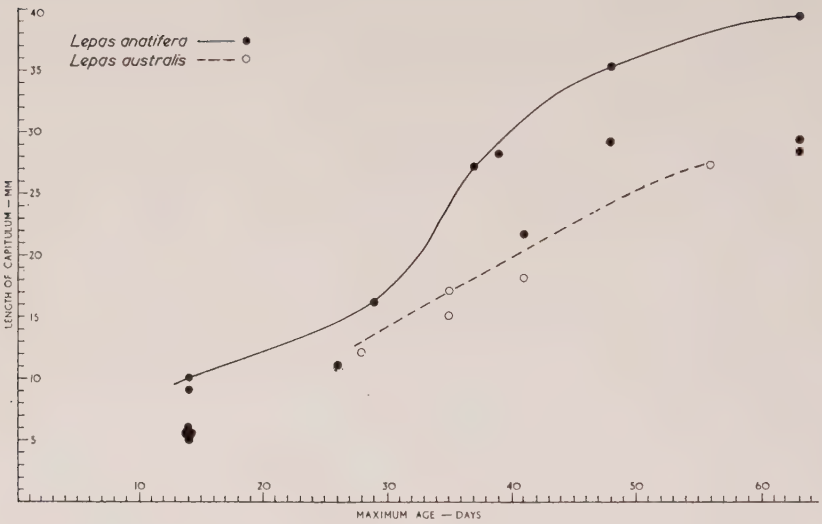

FIG. 2.— Curves plotting maximum rates of growth in *L. anatifera* var. *testudinata* and *L. australis* populations from survey beacons.

breadth 14 mm, length of peduncle 67 mm, breadth 7 mm (Nilsson-Cantell, 1928). In the Jennings Collection of Cirripedia, at present located in the Department of Zoology Museum, University of Canterbury, New Zealand, there is a specimen with a capitulum length of 42 mm (locality Waitakerei R., coll. W. R. B. Oliver). The largest *L. australis* specimen recorded appears to have been one with a capitulum length of 33·6 mm described by Hoek (1883) from collections of the *Challenger* Expedition, 1873–76. It appears, therefore, that var. *testudinata* of *L. anatifera*, when fully grown, reaches a much larger size than does *L. australis*.

Growth on Different Surfaces of Beacons

On all beacons examined, considerable differences were noted in the degree to which various surfaces were colonized by barnacles. While dense settlement occurred on the bottoms of beacon drums, relatively few barnacles grew on the sides. Moreover, it was evident that populations from these two areas differed in the sizes to which the barnacles had grown, those on the drum bottoms being smaller in capitulum dimensions but longer in length of peduncle than individuals attached to the beacon sides. This suggests that, as a result of competition,

capitulum growth may have been restricted and peduncle growth accelerated in the densely crowded populations on bottom surfaces. Taking side and bottom populations of *L. australis* from Beacon *iv* as an example, there was a highly significant difference between mean sizes of barnacles taken at random from each of these two surfaces.*

Surface	N	$\bar{x}$ (mm)	σ_x (mm)
Side	36	9·22	2·2
Bottom	40	5·91	3·0

* Applying the "Student's" "*t*" test, $t = 5{\cdot}3$; from tables, $t = 4{\cdot}0$ for $P = 0{\cdot}00006$.

In the same case, peduncle lengths in barnacles from drum-bottom populations were as much as 18 cm, whereas barnacles attached to the sides of drums had peduncles seldom exceeding 4·0 cm in length.

Reproductive Development

In *L. anatifera* populations, the smallest barnacles bearing ovigerous lamellae had a capitulum length of 23 mm (maximum age 37 days, from Beacon *I*). Embryonic development within the ova of this individual was at an early stage, whereas in barnacles 27 mm in capitulum length from Beacons *J* (39 days), *K* (41 days), *L* and *M* (48 days), fully developed nauplii were hatching from the egg masses. In each of the populations from the latter beacons there were larger barnacles in which no ovigerous lamellae were present, suggesting that there may be a considerable size variation between individual barnacles at the time ova are laid. This could arise from variations in growth rate and other extrinsic factors that may influence gametogenesis and the time taken for an individual barnacle to reach maturity. The larger barnacles from Beacons *N*, *O*, and *P* (63 days) mostly bore developed ova from which nauplii were hatching, and probably in those whose mantle cavities were devoid of lamellae the first brood of larvae had already been released. As no developing egg masses were found in barnacles from Beacon *H* (29 days) the data indicate that the processes of extrusion of ripe ova into the mantle cavity and fertilization may have taken place between 4 and 5 weeks after settlement, with fully developed nauplii hatching after the fifth week. Darwin (1851) reported the finding of a *L. anatifera* specimen with a capitulum of under half an inch (*c.* 13 mm) long, which bore mature ova, and this may provide further evidence that size may be no reliable guide to the reproductive state in these animals.

In the *L. australis* populations, nauplii were found hatching from the egg masses carried by barnacles from Beacon *v* (56 days) with a capitu-

lum length of 21 mm, while no ovigerous lamellae were evident in adults from Beacon *iv* (41 days). From this, the general conclusion may be drawn that the initial deposition of mature ova in the mantle cavity and the ultimate release of fully developed larvae occurred between some 6 and 8 weeks after settlement.

ACKOWLEDGEMENTS

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REFERENCES

ANNANDALE, N., 1909: The Rate of Growth in *Conchoderma* and *Lepas*. *Rec. Indian Mus. 3*: 295.

AURIVILLIUS, C. W., 1892: Neue Cirripedien aus dem Atlantischen, Indischen und Stillen Ocean. *Ofvers. af Kgl. Svenska Vet. Akad. Forh.* No. 3: 123–34.

BOETIUS, JAN, 1952–3: Some Notes on the Relation to the Substratum of *Lepas anatifera* L. and *Lepas fascicularis* E. & S. *Oikos 4* (2): 112–7.

BORRADAILE, L. A., 1916: British Antarctic (*Terra Nova*) Expedition, 1910. Natural History Report. Zoology. 3 (4) Crustacea, Part 3—Cirripedia: 127–36.

BROCH, Hj., 1922: Studies on Pacific Cirripedes (Papers from Dr Mortensen's Pacific Expedition, 1914–1916. 10). *Vidensk. Medd. dansk. naturh. Foren. Kbh., 73*: 215–358.

DARWIN, CHARLES, 1851: "A Monograph on the Sub-class Cirripedia. The Lepadidae, or Pedunculated Cirripedes." Ray Society, London, 400 pp.

HOEK, P. P. C., 1883: Report on the Cirripedia Collected by H.M.S. *Challenger* During the Years 1873–1876. *Report on the Scientific Results of the Voyage of H.M.S. Challenger, 1873-1876, 8*: 1-169.

————, 1907: The Cirripedia of the Siboga Expedition: A—Cirripedia Pedunculata. *Siboga Exped., Monogr. 31a*: 1–128.

JENNINGS, L. S., 1915: Pedunculate Cirripedia of New Zealand and Neighbouring Islands. *Trans. Proc. N.Z. Inst. 47*: 285–93.

KRUGER, P., 1940: Cirripedia. Bronn's Klassen u. Ordnungen d. Tierreichs, Bd. Abt. 1, Buch. 3, Tiel 3: 1–560.

NILSSON-CANTELL, C. A., 1928: Studies on Cirripeds in the British Museum (Nat. Hist.). *Ann. Mag. nat. Hist., ser. 10, 2* (7): 1–39.

ORTON, J. H., 1930: Experiments in the Sea on the Growth-inhibitive and Preservative Value of Poisonous Paints and Other Substances. *J. Mar. biol. Ass. U.K. 16*: 373–452.

SKERMAN, T. M., 1958: Notes on Settlement in *Lepas* Barnacles. *N.Z.J.Sci. 1*:

*STEPHENSEN, K., 1933: Havedderkopper (Pycnogonida) og Rankefodder (Cirripedia. *Danm. Fauna. 38.* Kobenhavn.

TARASOV. N. I.; ZEVINA, G. B., 1957: Usonogie raki (Cirripedia Thoracica) Morej SSSR. Fauna SSSR. *Zool. Inst. Akad. Nauk SSSR,* n.s. No. 69 Rakoobraznye (Crustacea) *6*: 1–267.

*Reference not seen by author.

DETECTION OF FOOD PRESERVATIVES BY PAPER CHROMATOGRAPHY

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Summary

This paper describes the separation of 19 food preservatives and some normal food constituents on a single chromatogram using buffered butanol-ethanol as solvent. Substances were detected in micro quantities by the use of a fluorescence quenching effect in combination with a colour reagent spray.

Introduction

Various authors have described chromatographic separation techniques for isolating aromatic acids and esters used in food preservation. Parkinson (1952) used buffered butanol-ethanol in the separation of benzoic, salicylic, p-hydroxybenzoic and p-chlorobenzoic acids. Jarczynski and Kiermeier (1954) employed butanol-ammonia in separating the esters of p-hydroxybenzoic acid, and Clemens (1955) reported methanol-water as a suitable solvent for the latter separation.

In addition to the substances mentioned above, a wider range of preservatives of the benzoic acid group, vanillic esters (Banfield, 1952; Pearl & McCoy, 1945), sorbic acid (Melnick *et al.*, 1956), monochloracetic acid and thiourea require to be detected in foodstuffs by the analyst. It is the purpose of this paper to describe the separation and detection methods used in this laboratory to indicate the presence of preservatives in foodstuffs.

Experimental

Reference Compounds

Nos 4, 7-9, 11-18 (see Table 1). BDH Analytical or Laboratory grade reagents.

Nos 1-3, 5-6, 19. Laboratory preparations.

No. 10. Supplied by Hoechst, Frankfurt.

The melting points of these compounds agreed with those given in the literature, and single spots were formed on the chromatogram in all cases.

Solvent System

n-butanol/ethanol/3N ammonia/3N ammonium carbonate, (40:11:9·5:9·5), (Fewster & Hall, 1951).

Detection of Spots

(a) The ultraviolet light—fluorescent screen technique described by Grieg (1952) was applied, using an eosine-sprayed sheet and a short wave length ultraviolet (U.V.) lamp. (The Hanovia "Dectectolite", 2537A, was used.)

(b) Diazotised p-nitroaniline spray (PNA) (Bray *et al.*, 1950).

25ml of 0·3% p-nitroaniline in 8% HCl was mixed with 1·5ml of 5% $NaNO_2$ immediately prior to use. This was followed by a spray of 20% Na_2CO_3.

PROCEDURE

20g of the foodstuff diluted or macerated with water, or 50ml of undiluted beverage, was acidified, 10ml of alcohol added, and extracted for four hours with chloroform in a liquid-liquid extractor. (The addition of alcohol is necessary in order to facilitate the extraction of monochloracetic acid should this be present in the foodstuff.)

The extract was evaporated in a stream of warm air, the residue dissolved in 1ml of alcohol, and 5, 25, and 100ml lots spotted on to Whatman's No. 1 filter paper (23 × 35 cm). For a 20g sample, this represents 50μg of the preservative over a 25 to 500 p.p.m. range. 20μl of a standard reference solution containing salicylic, benzoic, m- and p-hydroxybenzoic acids (each 0·25% w/v) was spotted alongside the sample. The ascending chromatogram was developed at 20°C for 18 hours without first equilibrating the paper, and the solvent front reached about 30 cm. The paper was dried for 30 min. in a stream of warm air, and then examined with a U.V. lamp as described above (Grieg, 1952), the spots being outlined in pencil. A light spray of diazotised p-nitroaniline was then applied, followed by a heavier spray of sodium carbonate, and the paper left to dry in the air.

Should a streak on the chromatogram mask the position of the spots, this can be eliminated by pretreatment of the sample as described in the A.O.A.C. Methods (1955). Thus, the diluted sample was saturated with salt, made alkaline, and filtered after standing for 2 hours, and an aliquot of the filtrate was acidified and extracted as before.

RESULTS AND DISCUSSION

Table 1 lists the Rf values of the preservatives and of some food constituents, and gives their limits of detection. With the U.V.-fluorescent screen technique 1μg of salicylic acid shows as a fluorescent spot, and the other preservatives, with the exception of monochloracetic acid, appear as well-defined dark spots on the fluorescent screen. Most of the preservatives are detectable at the 1-5μg level. The PNA

spray detects 1μg of m- and p-hydroxybenzoic acids (red), 1μg of vanillic acid (purple), 5μg of salicylic acid (orange), and 5μg of thiourea (yellow). This spray, therefore, affords an excellent confirmation of the presence of these five substances, while having the added advantage of colouring the vanillic esters mauve (10μg), and the remaining preservatives pink when present to the extent of 30-50μg (Table 1). Below 50μg the pink colour is not always distinguishable owing to background colour, though the latter is minimized by adequate exposure of the paper to a stream of air before spraying. The spray is a necessary aid in the identification of the preservatives, as some normal food constituents which are also detected by the ultra violet technique may have Rf values similar to those of the preservatives. For example, fresh tomato extract gave a spot corresponding to m-hydroxybenzoic acid, but which sprayed blue with PNA.

Aliphatic acids which may be present in foodstuffs cause no interference. Formic, acetic, and propionic acids are not detected, and the addition of acetic acid to the reference solution caused no displacement of Rf values. Oxalic, succinic, malic, tartaric, and citric acids spray pink with PNA, but do not move from the origin, while lactic, glycollic and ascorbic acids move only slightly (Table 1). Lactic acid (Rf 0·18) is easily distinguished from p-hydroxybenzoic acid (Rf 0·20) and vanillic acid (Rf 0·15) by the bright pink colour formed with PNA as well as by the fact that it is not visible under U.V.

As vanillin and coumarin appear on the chromatogram with widely different Rf values (0·47 and 0·90), they can be detected by this method when present in foodstuffs, and also in vanilla essences which may be spotted directly on to the paper. Vanillin is distinguished from sorbic acid and o-chlorobenzoic acid, by the mauve colour formed with PNA and also by a dull mauve fluorescence when the sprayed chromatogram is viewed with a U.V. lamp. Coumarin, which may otherwise be confused with butyl vanillate owing to its similar Rf value and mauve colour with PNA, is clearly confirmed by the bright green fluorescence produced when the chromatogram is sprayed with N NaOH alone (Swain, 1953), (sensitivity 1μg).

Salicylic acid, which has the same Rf as cinnamic acid, is easily distinguished by its bright fluorescence. Sorbic, cinnamic, and o-chlorobenzoic acids may be further separated by developing a continuous descending chromatogram with the same solvent for about 48 hours, along with control spots of the three acids. Attempts to separate these acids with a variety of other solvent systems were not successful.

When the individual preservatives were added to tomato sauce and beverage samples to give a concentration of 100 p.p.m., and the extracts chromatographed, the added preservative was detected in each case. The extraction of thiourea, which has a low solubility in chloroform, is aided by the addition of alcohol, but thiourea was also detected in a beverage containing 100 p.p.m. when the alcohol was omitted. Mono-

TABLE 1.—Rf Values and Limits of Detection.
Ascending chromatography at 20° C on Whatman No. 1 paper.
Solvent: butanol/ethanol/3N ammonia/3N ammonium carbonate (40:11: 9·5:9·5).

Preservative	*Rf*	*Limits of Detection under U.V. (μg)*	*Colour with PNA*	*Limits of detection with PNA (μg)*
1. Bu p-hydroxybenzoate	0·94	—	pink	50
2. Pr p-hydroxybenzoate	0·93	5	pink	50
3. Bu vanillate	0·91	10	mauve	10
4. Et p-hydroxybenzoate	0·91	5	pink	50
5. Et vanillate	0·83	10	mauve	10
6. Me p-hydroxybenzoate	0·83	5	pink	50
7. p-chlorobenzoic acid	0·63	2	pink	50
8. salicylic acid	0·58	1*	orange	5
9. cinnamic acid	0·58	2	pink	50
10. sorbic acid	0·55	1	pink	50
11. o-chlorobenzoic acid	0·53	50	pink	50
12. benzoic acid	0·48	10	pink	50
13. anisic acid	0·42	1	pink	50
14. thiourea	0·39	5	yellow	5
15. m-hydroxybenzoic acid	0·30	5	red	1
16. furoic acid	0·29	1	pink	50
17. monochloracetic acid	0·28	(not detected)	pink	100
18. p-hydroxybenzoic acid	0·20	1	red	1
19. vanillic acid	0·15	1	purple	1
Food Constituent				
20. coumarin	0·90	10†	mauve	
21. vanillin	0·47	2	pink-mauve	
22. lactic acid	0·18	(not detected)	pink	
23. glycollic acid	0·10	(not detected)	pink	
24. ascorbic acid	0·06	(not detected)	pink	
25. citric acid	0	(not detected)	pink	
26. tartaric acid	0	(not detected)	pink	
27. carotene	0	—	—	

*fluorescent

†detected at 1μg level if sprayed with N.NaOH first

chloracetic acid was satisfactorily detected in a cordial to which a quantity of the acid had been added to give a concentration of 100 p.p.m. It is not detected by ultraviolet light, but 100μg appears as a pink spot with PNA.

The method was applied successfully to many samples of tomato sauce, chili sauce, tinned fruit and vegetables, and beverages. Only in rare cases was pretreatment of the sample necessary. In applying this pretreatment to one sample, a tomato sauce which was showing a streak on the chromatogram, four preservatives, in addition to the

sodium benzoate already present, were added, i.e., ethyl p-hydroxybenzoate, m- and p-hydroxybenzoic acids, and sorbic acid (100 p.p.m. of each). The streak was eliminated and all five preservatives were clearly detectable.

The solvent system used in this method has been used by previous authors (Parkinson, 1952; Fewster & Hall, 1951) and was adopted after a number of other solvent systems had been investigated. The butanol/pyridine/ammonia system used by Safina (1956) resulted in increased Rf values with no improvement in the separations. The use of other alcohols in place of butanol, variation in solvent proportions, and replacement of the buffer by organic bases (pyridine and ethylene diamine) were of no advantage, while the use of organic acids (formic and acetic acids) or ethyl acetate increased the rate excessively. Solvents incorporating benzene, acetone, and petroleum ether were not found to be satisfactory.

The use of fluorescence-quenching effect for the detection of the spots was a decided improvement over the reliance on sprays alone. Diazotised p-nitroaniline was chosen on account of its selectivity, but indicator sprays were useful in confirming the acidity of the spots. Bromo-phenol blue—methyl red in a phosphate buffer, used by Fewster and Hall (1951), was found the most sensitive.

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REFERENCES

ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS, 1955: "Official Methods of Analysis of the Association of Official Agricultural Chemists", 8th edit. p. 487. Association of Official Agricultural Chemists Washington, D.C.

BANFIELD, F. H., 1952: *Chem. & Ind.* p. 114.

BRAY, H. G.; THORPE, W. V.; WHITE, K., 1950: *Biochem. J. 46* : 271.

CLEMENS, W., 1955: *Fette-Seifen-Anstrichmittel. 57* : 109.

FEWSTER, M. E.; HALL, D. A., 1951: *Nature, Lond. 168* : 78.

GRIEG, A., 1952: *Nature, Lond. 170* : 845.

JARCZYNSKI, R.; KIERMEIER, F., 1954: *Z. LebensmittUntersuch 99* : 91.

MELNICK, D.; VAHLTEICH, H. W.; HACKETT, A., 1956: *Food Res. 21* : 133.

PARKINSON, T. L., 1952: *Analyst 77* : 439.

PEARL, I. A.; MCCOY, J. F., 1945: *Food Ind. 17* : 1458.

SAFINA, G., 1956: *Conserve e deriv. agrumari 20* : 191. Seen only in *Chem. Abstr. 51* : 9031i. 1957.

SWAIN, T., 1953: *Biochem. J. 53* : 200

THE COLLECTION OF *Hylemyia seneciella* (Meade) (Diptera, Muscidae) FOR SHIPMENT TO AUSTRALIA

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(Received for publication, 10 July 1958.)

Summary

This paper records the collection of puparia of *Hylemyia seneciella* (Meade), the ragwort seed-fly, for dispatch to Australia. The methods used in the insectary for collection of puparia from field-collected infested ragwort are detailed. A total of approximately four thousand puparia was dispatched during February 1958.

In the 1957–58 season, there was an apparent lack of synchronization between the main crop of ragwort flowers and the presence of adults of the ragwort seed-fly. The general level of infestation in the field was much lower than that reported for the 1949–50 and 1953–54 seasons.

Introduction

The biological control of ragwort (*Senecio jacobaea* L.) in New Zealand was first attempted in 1927 (Miller, 1929). The insect introduced at that time was the cinnabar moth (*Tyria jacobaeae* L.). Despite early promise of the successful control of ragwort, the cinnabar moth was unable to establish itself widely in the field (Miller, 1940). A second insect, the ragwort seed-fly (*Hylemia seneciella* (Meade)), was then imported and, after study, liberated at a restricted number of localities in the North Island. The successful establishment of *Hylemyia seneciella* in one locality was recorded by Kelsey (1955). The larvae of the ragwort seed-fly live in the developing capitula and devour the seeds, each larva confining its activities to one capitulum. Even where all the seeds in a head are not destroyed, the remainder are usually rendered infertile (Kelsey, 1955).

During 1957, a request was received from the Division of Entomology, Commonwealth Scientific and Industrial Research Organization, Australia, for the collection and dispatch to Australia of a large number of puparia of *Hylemyia seneciella*. The above-named organization is currently engaged on the attempted biological control of ragwort. This paper records the collection and dispatch of puparia in response to this request.

Field Collection of Infested Ragwort Inflorescences

The area where ragwort seed-fly was initially liberated was inspected on 22 January 1958. During the previous two years, changes in farm management practice had led to the area being grazed by sheep, whereas during the preceding 19 years the area had been grazed principally by cattle. The small remnant of ragwort remaining was examined for

evidence of attack by seed-fly. The level of infestation was very low, but this may have been due to a retardation of ragwort flowering following grazing by sheep. A stand of ragwort approximately ten acres in extent was found at a distance of 2 miles from the liberation site. An examination of these plants revealed a moderate level of infestation by ragwort seed-fly. Only the earlier capitula in each inflorescence showed the characteristic tufting caused by the de-seeded flower being forced out beyond the surface of the surrounding florets. A subsequent microscopic examination of material from this area confirmed that in the 1958 season there had been an apparent lack of synchronization between the presence of adult females of *Hylemyia senneciella* and the main crop of ragwort flowers. The general level of infestation in the field was much lower than that reported by Kelsey (1955) for the 1949–50 and 1953–54 seasons. This may have been due to unfavourable climatic conditions for floral initiation earlier in the summer.

A large number of inflorescences was cut from this stand, care being taken to select only those that appeared to have a moderate level of infestation. On 28 January 1958, a further supply of infested heads was obtained from the same source.

Pupation of Field-collected Larvae

When the larvae of the seed-fly are fully fed, they bore through the base of the capitulum and drop to the ground, tunnelling into the soil before pupating. Shallow trays 36 in. by 18 in. were filled to a depth of 1½ in. to 2 in. with slightly moistened finely sieved river sand. It was thought that this material would provide a suitable site for pupation and at the same time facilitate the collection of puparia at a later date.

Approximately twenty-four hours elapsed between collection of material in the field and the setting-up of material over sand trays in the insectary. To minimize moisture loss in plant material during this period, the cut ends of the stalks of ragwort were covered with moist sacking. Examination of inflorescences had shown that only the earlier flowering capitula were infested, so the majority of the main crop of uninfested flowers was stripped, to reduce the bulk of material to be handled in the insectary. Plant material collected on 22 January was placed with the cut ends of the stalks in troughs of water to a depth of 4 in. and the inflorescences inclined at an angle of approximately 45° over the trays of sand. One trough was placed on either side of each sand tray.

Within twenty-four hours of setting out the material, maggots were dropping from the heads and wandering on the surface of the sand in the trays. The sand surface was relatively smooth, and apparently did not provide sufficient purchase for the larvae to tunnel. When the surface of the sand was disturbed by light stirring, larvae were able to tunnel in within a short time. At all subsequent waterings of the sand to

FIG. 1.—Ragwort inflorescences held over sand trays for the collection of puparia of *Hylemyia seneciella* (Meade).

maintain the moisture level, the surface was disturbed, and all larvae were able to tunnel quickly into the sand.

After 3 to 4 days in the insectary, a considerable amount of mould growth occurred in the tightly clustered ragwort heads. This mould growth was due to the high level of humidity among the heads, occasioned by the open water surface in the troughs. While this fungous growth would probably not be directly harmful to the seed-fly larvae, it would reduce their available food supply, and the webbing of fungous hyphae would restrict the free dropping of larvae from the heads once they had finished feeding.

In order to avoid this growth of mould, an alternative method of holding the ragwort inflorescences over the sand trays was devised. Wooden frames 6 ft by 2 ft covered with $\frac{1}{2}$ in. wire netting were supported above pairs of sand trays with the netting about 6 in. above the surface of the sand. The plant material was removed from the troughs and tied in loose bundles and inverted on the netting (Fig. 1). Mould growth did not increase and the ability of larvae to drop from the heads was not impaired.

Plant material collected on 28 January was set up over the trays on wire netting. A total of sixteen trays was used with three bundles of plant material per tray. From time to time, the capitula were examined to determine the number of larvae remaining in the heads. By 10 February, the majority of the larvae had dropped to the sand and the bulk of the larvae in the trays had constructed puparia. To ensure pupation of all the larvae in the trays, collection of puparia from the sand was delayed until 18 February.

Recovery of Puparia from Sand

The sand from the trays was first sieved through a $\frac{1}{4}$ in. mesh screen to break up any aggregates formed during watering and to remove the coarser debris dropped on the trays from the drying plant material. A second sieving through a screen with 12 meshes to the linear inch removed the bulk of the fine sand but retained the puparia. The remaining sand containing the puparia was then passed through a slotted screen with holes measuring $\frac{1}{2}$ in. by $\frac{5}{64}$ in. This screen retained the bulk of the coarser sand particles but allowed the majority of the puparia through. A final sieving was made through a screen having 15 meshes to the linear inch in one direction and 3 meshes to the linear inch in the other direction. This sieve retained all the puparia and only sand particles of similar size. Final separation of puparia from debris was made by spreading material in a thin layer and picking up the puparia with a small paper scoop. The puparia were then held in shallow layers of fine sand in petri dishes pending completion of formalities for dispatch.

The total yield of puparia from sixteen trays was approximately 4,200, the highest number per tray being 712 and the lowest 116. The greatest number of puparia was collected from ragwort heads taken in the field on 22 January. By 28 January, a proportion of larvae in the field had completed feeding and dropped from the heads. This was confirmed by an examination of capitula on 29 January and by the fact that a substantial number of larvae dropped from the heads of ragwort during transit from the field to the insectary. Very few larvae dropped in transit from heads collected on 22 January.

During the final separation of puparia from debris, all dead, damaged, and diseased puparia from eight trays were put aside for further examination. At the same time, 33 dead larvae were recovered from the trays and examined under the microscope. Thirty-two larvae were infected by nematodes of the genus *Rhabditis* and one larva had been invaded by a fungus. Twenty-one puparia were examined, fourteen were apparently parasitized by a fungus, two by the nematode referred to above, three had suffered mechanical damage, and in two cases the apparent cause of death could not be determined. The low level of mechanical damage indicated that the separation of puparia from sand by sieving is an acceptable technique. If a high percentage of abnormal flies emerge from this material, internal damage due to shaking might

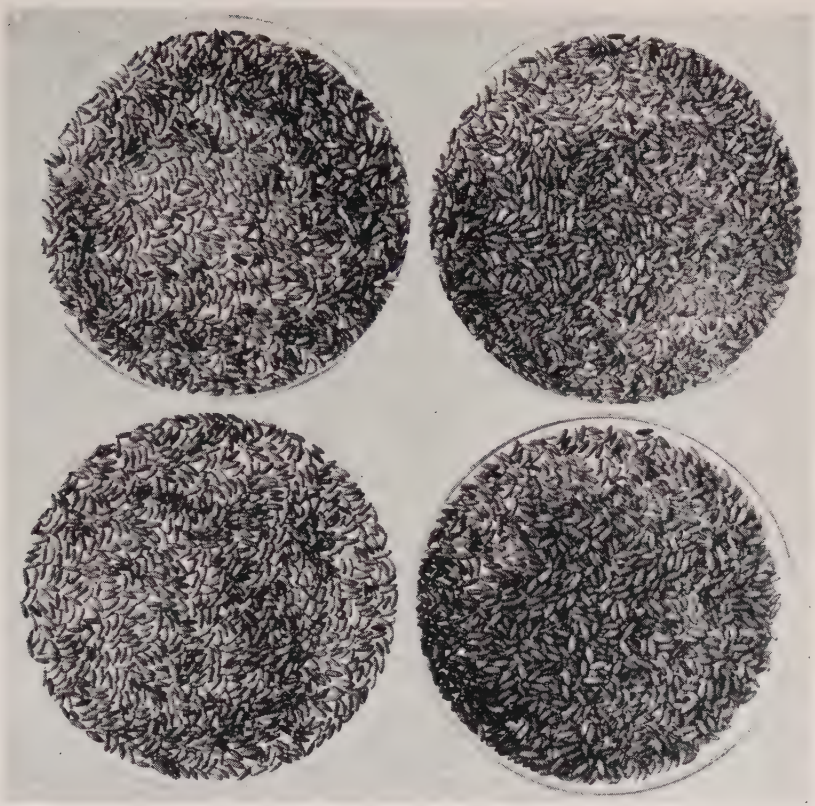

FIG. 2.—Total consignment of approximately 4,000 puparia of *Hylemyia seneciella* (Meade), showing clean state of puparia following sieving.

be suspected. The majority of species in the nematode genus *Rhabditis* are saprophytic, so that the larvae and puparia infected by nematodes had either died from other causes or had been injured in the trays.

PACKING AND DISPATCH OF PUPARIA

Puparia were recovered from the holding dishes by a single screening through a 15 × 3 mesh sieve. The clean state of the material can be seen in Fig. 2, which shows the total collection of more than 4,000 puparia.

The puparia, in lots of approximately 200, were thinly spread on pads of cotton wool, which were then rolled up and inserted in 4 in. by 1 in. glass tubes in which a bottom pad of cotton wool had been placed. The

tubes were plugged with cotton wool; 20 such tubes were placed in layers of cotton wool in a stout wooden box.

The container was dispatched on 26 February to Canberra by express air freight, arriving within 48 hours of leaving Palmerston North. This consignment should provide a nucleus of seed-fly for use against ragwort in Australia.

The number of adults emerging from puparia will not be known until November or December 1958.

ACKOWLEDGEMENTS

The writer is indebted to the staff of the Entomology Division, Palmerston North, for assistance both in the field and in the insectary, and to Mr H. Drake for the photographs.

REFERENCES

KELSEY, J. M., 1955: Ragwort Seed-fly Establishment in New Zealand. *N.Z. J. Sci. Tech., A 36*: 605–7.

MILLER, D., 1929: Control of Ragwort: Experimental Work with Cinnabar Moth. *N.Z. J. Sci. Tech. 11*: 112–9.

———, 1940: Biological Control of Noxious Weeds of New Zealand. *Herb. Pub. Ser. Bull. 27*: 153-7.

A NOTE ON THE DETERMINATION OF LOW CONCENTRATIONS OF SULPHATE IN RAIN AND OTHER WATERS

By J. K. Johannesson, Wellington City Council Laboratory

(Received for publication, 7 May 1958)

The available methods for determination of sulphate in rain and other waters when the concentration is less than 10 p.p.m. are difficult and of low precision.

The author here presents a novel and direct method of doing this determination which is rapid and of a greater precision in the range 0 to 10 p.p.m. sulphate than previously published methods for such low concentrations. The principle of the method is that, when a solution containing only sulphuric and hydrochloric acids, such as is obtained by treatment of a natural water with an ion exchange resin of the cation type, is treated with mercuric oxide, very poorly conducting mercuric chloride and conducting mercuric sulphate are formed. The sulphate is then determined by measuring the conductivity of the resulting solution, which is almost entirely due to the sulphate with a very small contribution from the chloride, for which a small correction is made.

Method

A suitable quantity of the solution is passed through a small Amberlite IR 120 column in the hydrogen form, to remove all cations. The first portion passing the column is discarded and the remainder collected. A 100ml aliquot is briefly boiled to remove carbon dioxide derived from bicarbonate in the original sample, cooled, 1·0ml of 1:20 HCl added followed by an excess of solid mercuric oxide, and the mixture allowed to come to temperature equilibrium in a thermostatically controlled water bath at 30° C. This temperature was chosen as being above what the ambient temperature would reach, except on rare occasions.

The conductivity is then determined and the sulphate content derived from a standard curve (Fig. 1) prepared by treating sulphuric acid solution with the 1:20 hydrochloric acid and mercuric oxide as described above. (1·0ml of 0·02 N sulphuric acid/100ml = 9·8 p.p.m. SO_4''.) For concentrations greater than 10 p.p.m. the samples should be diluted so as to lie within this range.

The shape of the standard curve is slightly affected by the presence of the mercuric chloride derived from both added and original chloride.

This presence of chloride contributes a small error and should be corrected for. Figure 2 shows such a correction curve by adding vary-

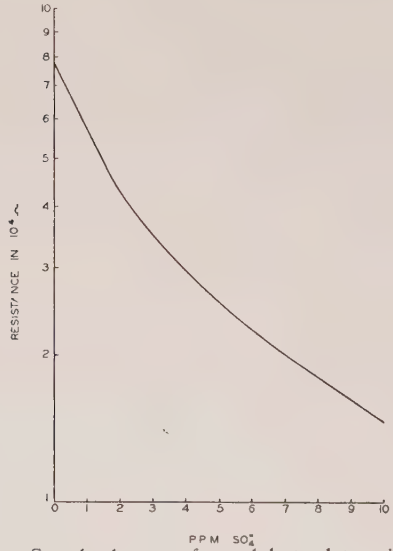

FIG. 1.—Standard curve for sulphate determination.

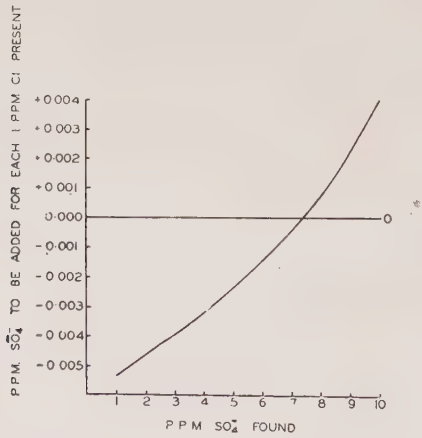

FIG. 2.—Correction curve for chloride content.

ing amounts of chloride to standard sulphate solutions. The correction is small.

Interference has been found only from nitrate in upland waters and from both nitrate and silicate in ground waters. Investigations are proceeding to overcome these difficulties. Nitrates may be allowed for by the use of a correction curve as for chloride. This method has been in routine use in this laboratory for more than a year and has given good results especially when the sulphate content of the rain water has been less than 1·0 p.p.m.

THE APPLICATION OF TABLE FLOTATION TO THE REMOVAL OF SULPHIDES FROM A SCHEELITE CONCENTRATE

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(Received for publication, 18 July 1958)

Summary

The application of table flotation to the upgrading and the elimination of arsenic from a scheelite concentrate containing an appreciable amount of sulphides is described. The sample tested was one resulting from gravity concentration of ore mined from scheelite-bearing reefs at Glenorchy, Central Otago. From a sample assaying 43·3% WO_3 and 2·3% arsenic and containing from 15% to 20% of sulphides in clean and oxidized condition, a product containing 96·9% of the WO_3 and assaying 68·1% WO_3 and 0·09% arsenic was obtained. The resulting product, in contrast to the concentrate received for testing, was a marketable one and was not subject to penalty for low WO_3 content or high arsenic content.

The development and technique of table flotation are described in detail, and the particular suitability of the process to the problem is discussed. Test results and test conditions covering both the table floating of the sulphides and the table floating of the scheelite are reported in detail.

Introduction

In the Glenorchy area, a number of scheelite-bearing reefs containing an appreciable amount of sulphide mineralization are worked for the recovery of scheelite. Gravity concentration of this ore on a Wilfley table frequently results in the production of a concentrate low in WO_3 content and excessive in arsenic content due to the combined recovery of the heavy minerals, scheelite, pyrite, and arsenopyrite.

The present conditions of sale for scheelite concentrates specify a minimum of 65% WO_3, a maximum of 1·5% tin, and a maximum of 0·2% arsenic. Penalties are deducted for ore from 65% WO_3 down to 55% WO_3, below which figure shipment may be refused. Arsenic is acceptable up to 2·0%, but between 0·2% and 2·0% carries increasing penalties, and a concentrate assaying more than 2·0% is not readily marketable. Tin minerals are not present in the Glenorchy scheelite reefs, and therefore the tin content of concentrates is not of interest in this investigation.

A sample of gravity concentrate submitted for testing assayed 43·3% WO_3, 2·3% arsenic, and contained from 15% to 20% of sulphides. Microscopic examination of the sample showed that the sulphides consisted of single crystals or aggregates of crystals of iron pyrites

and arsenopyrites, some being clean and bright, but the majority showing oxidation varying from a slight tarnish to a complete pseudomorph in limonite.

There was a wide range of particle size in the sample, as shown by the sizing analysis in Table 1.

TABLE 1.—Sizing Analysis of Gravity Concentrate Received for Testing.

B.S.S. mesh	Weight %	Cumulative weight %
+7	0·2	0·2
7/14	1·8	2·0
14/25	7·2	9·2
25/52	16·2	25·4
52/100	31·4	56·8
100/200	34·2	91·0
—200	9·0	—
Total	100·0	

Test work was undertaken to determine whether the sulphide minerals could be eliminated so as to render the gravity concentrate marketable in respect of both WO_3 and arsenic content.

POSSIBLE TREATMENT METHODS

In evaluating the possible methods that could be used to beneficiate the sample, the following factors required consideration:

(1) The amount of sample preparation necessary prior to treatment;

(2) The cost of plant required for the treatment and the plant operating cost;

(3) The technical skill required to operate the plant and for control of the treatment process;

(4) The separation, and grade of concentrate, that could be achieved by the treatment;

(5) The recovery of WO_3 obtainable by the treatment.

The first-mentioned factor was important because grinding of the gravity concentrate was to be avoided if possible, because of the sliming characteristics of scheelite. In subsequent concentrating operations, the presence of slime would encourage losses in WO_3. The second and third factors were of particular importance because of the location of Glen-

orchy and because of the existing methods of concentrating the scheelite used there. The remaining two factors are significant in evaluating any beneficiating process.

Having regard for these factors, the following treatment methods were considered to have the greatest possibilities:

(1) Roasting for arsenic removal followed by further tabling to increase the WO_3 content.

(2) Froth flotation of the sulphides from the scheelite or the scheelite from the sulphides.

(3) Table flotation of the sulphides from the scheelite or the scheelite from the sulphides.

Gravity concentration would not be suitable, as the concentrate had already been obtained by this method. Electrostatic separation has recently been applied with success to the beneficiation of scheelite-sulphide concentrates, the method having the advantage of being as effective on weathered ore as on freshly broken ore. Due to the cost of high-tension equipment, however, electrostatic separation was not considered feasible.

Roasting of the concentrate would probably eliminate most of the arsenic, but the fineness of the ore would necessitate roasting in a well-controlled and expensive furnace with provision for rabbling. Capital and operating costs would be high, and to bring the product up to an acceptable grade tabling or magnetic concentration of the roasted product would be necessary.

Flotation of either the sulphides from the scheelite or the scheelite from the sulphides was considered a logical approach to the problem. The flotation of the sulphides would be difficult, however, due to their varying states of oxidation; clean sulphides would be readily floated, but the oxidized ones extremely difficult to recover in this way. The other serious disadvantage of using flotation treatment would be that the sample would require grinding to at least —72 mesh (B.S.S.), and appreciable losses of scheelite could be expected as a result. In view of these disadvantages and because preliminary work on a similar sample had indicated the limitations of flotation treatment, the method was passed over in favour of table flotation.

Table flotation, frequently referred to as agglomeration tabling, is a process which, although used in a slightly modified form before froth flotation was developed, is now becoming very important in mineral beneficiating. This process appealed because it could be applied to material much coarser than that needed for froth flotation, required less technical skill to control, and could be carried out on a Wilfley table, which was already used for gravity concentration at Glenorchy.

Separation by table flotation had two possibilities, either agglomeration and removal of the sulphides or agglomeration and removal of the scheelite. Because of the encouraging features of the process, test work to determine its application in the treatment of the Glenorchy sample was undertaken. The outstanding results obtained, the increased interest

in the process in recent years, and the technique involved, make the process worthy of a detailed discussion and description.

THE TECHNIQUE OF TABLE FLOTATION

The need for a process possessing the same selectivity as flotation, dependent only on surface characteristics of the minerals not on their specific gravities, and operating on a much coarser material had been apparent for some years when table flotation was developed and introduced. The process has all the advantages of froth flotation, and such fine grinding of feed prior to treatment is not required—i.e., conditions are such that larger particles can be made to float. The disadvantages of the process are that the material to be treated must be deslimed (not a problem in this investigation, as the feed is a gravity concentrate) and the products are contaminated with a heavy oil.

In the process, advantage is taken of the preferential oiling of one of the mineral components resulting in the formation of agglomerates which either float on the surface of the water on the table or ride lightly over the other unoiled components which cling to the surface of the table in the usual way. A separation not dependent on specific gravity is thus obtained. Air may be added to the table to improve buoyancy of the agglomerated particles and facilitate their removal.

The basis of the technique is not new; a similar oiling process called skin flotation was tried more than fifty years ago, but failed owing to the lack of selective reagents. It gave way, following further research, to the modern widely used froth flotation process. Although the process has limited rather than general application as a concentrating method, it has already been used successfully for the concentration of phosphates, carbonates, sulphides, and oxides.

Available information on the problem indicated that the oiling and removal of the sulphides would be the more practical approach, but, because of the oxidation of the sulphides and the desirability of increasing table capacity by floating the more abundant component, the flotation of the scheelite was also tested. In this respect, table floation is the reverse of froth flotation, as in the latter process the flotation of the least abundant component is usual.

EXPERIMENTAL PROCEDURE

The gravity concentrate samples prepared for testing were conditioned in an earthenware jar fitted with plastic lifters. Selected reagents were added, the pulp density made up to 80% solids by weight, and the mixture conditioned for the desired time by rotating the jar on rollers. The jar was tilted upwards and remained open at one end to allow free admission of air, the trapping of air in the charge during conditioning being considered desirable (Fig. 1). Conditioning times for reagents

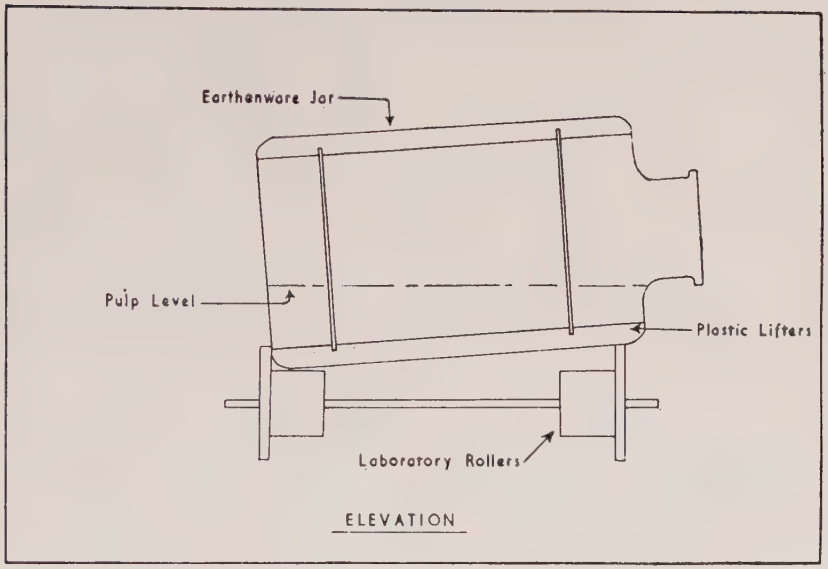

FIG. 1.

varied, but in most cases samples were conditioned with xanthate for 15 min. or with R708 (an American Cyanamid reagent) for 10 min. before the addition of fuel oil, the conditioning time for which is shown in the tabulated experimental results.

Apart from fuel oil, the reagents selected for the process were those most frequently used for froth flotation of the minerals concerned. For the flotation of the sulphides, xanthates (collectors), copper sulphate (activator), sodium carbonate (pH modifier), and potassium sulphide (sulphurdizer) were used. For the flotation of scheelite, R708 and sodium oleate (collectors), sodium carbonate (pH modifier), sodium cyanide (sulphide depressant), sodium sulphide (a sulphide depressant when used in excess), sodium silicate (a gangue depressant), and cresylic acid (a frother to assist aeration) were used.

When reagent addition and conditioning were complete, the liquid was decanted and the sample transferred to the feeder above the Wilfley table. The feed section of the distribution launder along the top of the table was removed, but the wash water section was retained. On the surface of the table above the top riffle in the section usually occupied by the feed launder, a piece of hardboard was used to raise the deck of the table to the height of the first riffle. The conditioned feed dropped on to this platform and was washed down by a thin sheet of water provided by a number of fine jets. (Fig. 2).

In most of the tests, compressed air jets were played on to the surface of the table to further expose the material to air and to assist flotation.

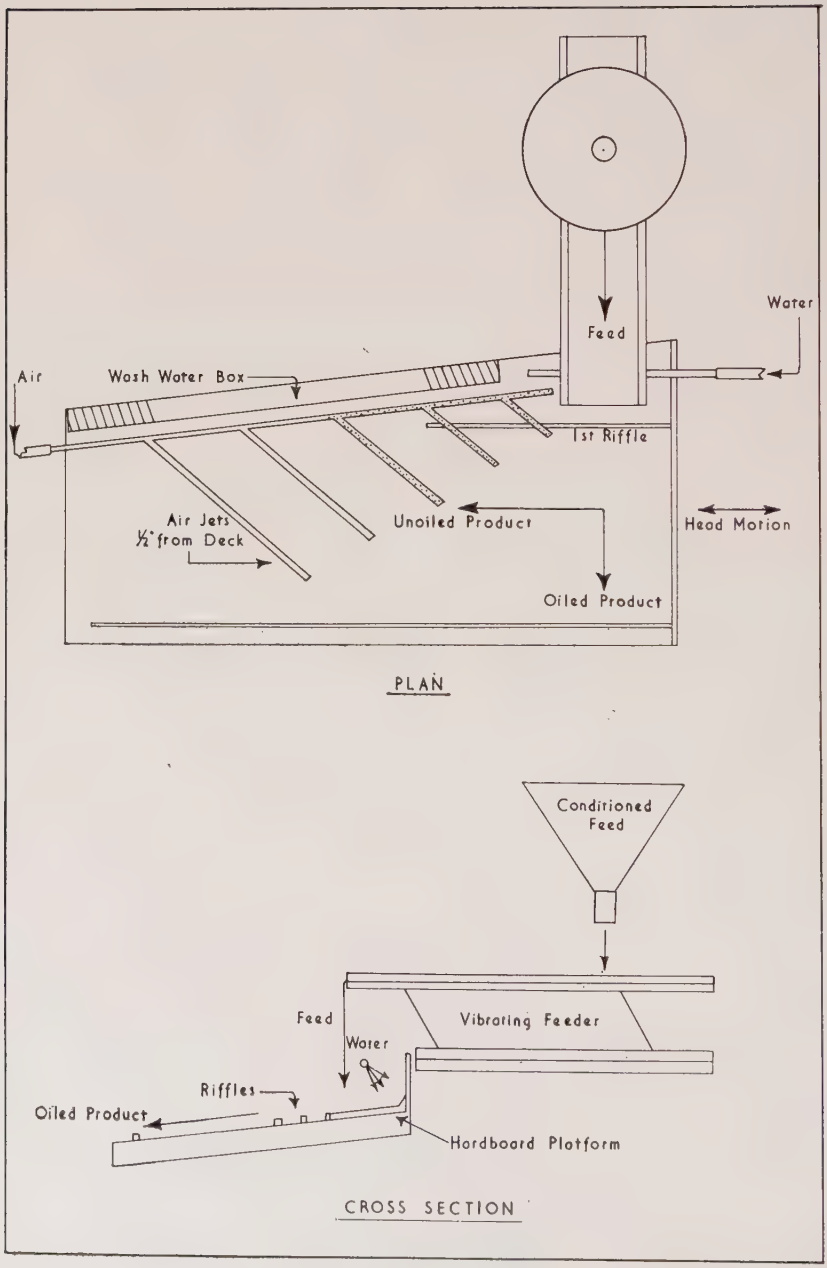
Feed
Water
Air
Wash Water Box
1st Riffle
Air Jets
½" from Deck
Unoiled Product
Head Motion
Oiled Product
PLAN
Conditioned
Feed
Feed
Vibrating Feeder
Water
Riffles
Oiled Product
Hardboard Platform
CROSS SECTION

FIG. 2.

Air assisted in raising floatable material that had escaped from the surface film, but when scheelite was being floated was inclined to raise fine clean sulphides.

Test Results and Discussion

Following are details of the tests conducted and the results obtained in the investigation. Only the typical and more successful tests are reported. Throughout the investigation, analyses of products were kept to a minimum, and where they are not complete the WO_3 and arsenic distributions are calculated on the basis of the feed sample analysis, 43·3% WO_3 and 2·3% arsenic. Reagent quantities are quoted as pounds of reagent per short ton of concentrate treated.

Table Flotation of Sulphides

TABLE 2.—Test Conditions, Reagent Quantities, and Test Results in the Table Flotation of Sulphides.

Test No.	Na_2CO_3 (lb/ton)	$CuSO_4$ (lb/ton)	Ethyl xanthate (lb/ton)	Fuel oil (lb/ton)	pH	Conditioning (min)
1	2·0	2·0	0·4	10·0	7·0	30
2	2·0	1·0	0·4	10·0	7·6	15
3	2·0	2·0	0·4	10·0	6·6	30

Test No.	Product	Weight (%)	Assay		%Distribution	
			%WO_3	%As	WO_3	As
1	Concentrate	54·6	67·4	0·34	85·0	8·1
	Middling	32·0				
	Tailing	13·4				
	Feed	100·0	43·3	2·3	100·0	100·0
2	Concentrate	46·8	66·5	0·98	71·9	19·9
	Middling	33·2				
	Tailing	20·0				
	Feed	100·0	43·3	2·3	100·0	100·0
3	Concentrate	49·6	69·4	1·30	79·5	28·0
	Middling	28·8				
	Tailing	21·6				
	Feed	100·0	43·3	2·3	100·0	100·0

None of the above tests gave a scheelite concentrate sufficiently low in arsenic to escape penalty, but all tests resulted in a product acceptable in terms of both WO_3 and arsenic content, although recovery of scheelite was low. In one test, not reported, butyl xanthate, a higher xanthate than ethyl and a stronger sulphide promoter, was used without benefit, and in another test, the presence of potassium sulphide (a sulphurdizer for oxidized sulphides) caused depression of all minerals. This reagent, although an activator for tarnished sulphides, is a strong depressant for the same minerals when used in excess. Air was used on the table for all of the above tests and appeared to assist in the flotation of sulphides.

It was observed in these tests (five in all) that the tarnished sulphides would not float and therefore reported in the scheelite concentrate. The clean sulphides, however, floated without difficulty. In view of this difficulty, the test work was then directed towards floating the scheelite away from the sulphides.

TABLE FLOTATION OF SCHEELITE

TABLE 3.—Test Conditions, Reagent Quantities, and Test Results in the Table Flotation of Scheelite.

Test No.	Na_2CO_3 (lb/ton)	Na_2SiO_3 (lb/ton)	NaCN (lb/ton)	R708 (lb/ton)	Sod. oleate (lb/ton)	Fuel oil (lb/ton)	pH	Conditioning (min)
1	10·0	4·0	—	0·3	0·12	10·0	10·2	30
2	10·0	4·0	4·0	8·0	0·12	20·0	10·1	30
3	10·0	4·0	4·0	4·0	0·12	30·0	—	45
4	10·0	0·5	4·0	4·0	0·10	20·0	—	30
5	10·0	0·5	4·0	4·0	—	20·0*	—	30
6	10·0	0·5	4·0	4·0	—	15·0	10·0	30

*1·0 lb/ton of cresylic acid mixed with the fuel oil.

Test No.	Product	Weight (%)	Assay		%Distribution	
			%WO_3	%As	WO_3	As
1	Concentrate	63·2	64·4	0·31	94·0	8·5
	Middling	5·0				
	Tailing	31·8				
	Feed	100·0	43·3	2·3	100·0	100·0
2	Concentrate	57·7	68·5	0·09	91·3	2·3
	Middling	2·9				
	Tailing	39·4				
	Feed	100·0	43·3	2·3	100·0	100·0
3	Concentrate	46·6	71·0	0·05	76·4	1·0
	Middling	6·2				
	Tailing	47·2				
	Feed	100·0	43·3	2·3	100·0	100·0
4	Concentrate	52·4	70·3	0·17	82·0	3·9
	Middling	17·8	34·6		13·7	
	Tailing	29·8	6·4		4·3	
	Feed	100·0	44·9	2·3	100·0	100·0
5	Concentrate	52·6	70·3	0·05	84·6	1·2
	Middling	9·6	55·8	0·29	12·3	1·2
	Con. + mid.	62·2	68·1	0·09	96·9	2·4
	Tailing	37·8	3·6	5·94	3·1	97·6
	Feed	100·0	43·7	2·3	100·0	100·0
6	Concentrate	70·4	62·3	0·39	98·0	9·8
	Middling	0·8	27·3	1·24	0·5	0·4
	Tailing	28·8	2·3	8·76	1·5	89·8
	Feed	100·0	44·7	2·8	100·0	100·0

Twenty-two tests of this type were conducted and the results were much more encouraging. In nearly all the tests, an acceptable scheelite concentrate was produced, and in many a product not subject to penalty for an arsenic excess. In addition, scheelite recovery reached a most satisfactory level.

The results indicated that R708, sodium silicate, and sodium cyanide were all essential reagents. The use of sodium carbonate to raise the pH to 10·0 or more appeared necessary, as at this pH depression of sul-

phides was encouraged. Results showed that lime was not as satisfactory as sodium carbonate for pH control. Sodium oleate, a collector for non-metallic minerals, aided scheelite recovery at 0·12 lb/ton, but when used in greater amounts depressed this mineral. Cresylic acid was not evaluated, but appeared a desirable addition if not an essential one. It is claimed to facilitate the attachment of the fuel oil.

While carrying out these tests, it was observed that some of the largest scheelite particles were too heavy to respond to surface removal. They stayed down on the deck of the table and reported either in the sulphide tailing or in the middling product, depending on their size. The finer scheelite adhered readily to the air-water interface. As a result of this observation, the sample in Test No. 5 was stage reduced to —36 mesh (B.S.S.) and table floated in the usual manner. Improved results were obtained. In Test No. 6, only the —36 mesh (B.S.S.) portion of the gravity concentrate was treated, and again a high scheelite recovery at satisfactory grade resulted. In this test the pH of all water used was maintained at 10·0. The test was not as good as the previous one, however, possibly because the sample was conditioned in a steel mill and not in the earthenware one. This may have introduced ferric ions which can cause mineral activation, an effect requiring further investigation, because it could have important practical implications.

Air was used on the table in all tests reported except No. 2, and results indicated that it was desirable because of its effect in levitating the float product, even though it was inclined to induce flotation of fine sulphides.

Conclusion

Although further work would be necessary to determine the optimum operating conditions, reagent combination, and the effect of iron in conditioning, it is apparent that the table flotation process is a particularly suitable one for the treatment of the scheelite-sulphide gravity concentrate. The recovery of 96·9% of the WO_3 in a concentrate assaying 68·1% WO_3 from a sample assaying 43·3% WO_3 is a most satisfactory result. At the same time, the reduction of the arsenic from 2·3% to 0·09% brings this element well below the penalty limit. In addition, the simplicity of the method and the fact that a Wilfley table is the main item of equipment required makes the process an even more appropriate one for use at Glenorchy.

Laboratory work conducted with close control over test conditions gave most satisfactory results, and it is probable that, with continuous operation and recirculation of middling products, results at least equal to those reported in this paper could be obtained in full-scale operation. Reagent additions made in the test work were high and, although the cost of the reagents used may exceed twenty shillings per ton of concentrate treated, it is obvious that the treatment would be an economic one, and it is doubtful whether a more suitable or successful one could be developed.

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REFERENCES

ALLAN, J. C., 1952: Table Flotation for the Removal of Sulphides from Tin-Wolfram Concentrates in Portugal. *Trans. Instn. Min. Metall. Lond. 62 (3).*

BARTHELEMY, R. E., 1957: High Tension Separation of Scheelite Concentrate Eliminates Roasting Step. *World Min. 10 (11).*

MEHARRY, C. H. S., 1954: The Application of Table Flotation to the Removal of Arsenopyrite from Galena Concentrates and Silica from Lime Sands. *Proc. Aust. Inst. Min. Engrs. No. 173.*

MICHELL, F. B., 1945: Table Flotation. *Mining Mag. 62.*

RALSTON, O. C., 1937: Froth Flotation and Agglomeration of Tabling of Non-metallic Minerals. *Trans. Canad. Min. Inst. (Inst. Min. Metall.) 40.*

REED, J. J., 1945: The Scheelite Deposits of Glenorchy, New Zealand. *Trans. roy. Soc. N.Z. 75, Pt. 3.*

APPARATUS FOR INVESTIGATING SPATIAL DISTRIBUTION OF PLANKTON

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Summary

The apparatus described is designed to study the "meso-distribution" of marine plankton, and its relationship to the variable physical properties of sea water. "Meso-distribution" is defined as the spatial pattern which can be detected by horizontal sampling intervals not less than one metre and not greater than 100 metres. The investigation has been inspired by the marked departure from randomness shown by counts of replicate plankton samples, even in those from relatively (but not absolutely) homogeneous bodies of sea water. Temperature and salinity measurements can be made continuously in the same parcels of water from which the plankton is strained, and there is a possibility of measuring other variables by an extension of the same apparatus. Plankton is collected by a $1\frac{1}{2}$ in. diameter hose and centrifugal pump and filtered out on to bolting silk squares. Small samples (200 litres) of water are taken, and accurate total counts made of the organisms. Temperature is measured by a thermistor resistance thermometer, and salinity by conductivity measurement with a 4kc/s A.C. bridge, a conventional cell, and temperature compensation by a thermistor. Preliminary results are briefly discussed.

Introduction

The apparatus to be described, incorporates three techniques familiar to planktologists: the plankton pump, the electrical resistance thermometer, and the electrical conductivity method of estimating salinity. While none of these techniques is in itself new, the assembly of these components into one integral apparatus permits a new approach to the study of the behaviour of plankton in relation to its environment. Collier (1957) has described the "Gulf-II" sampler which has some features similar to those of the present apparatus. There is, however, one fundamental distinction in that "Gulf-II" is employed primarily for geographical investigations, whereas the apparatus described is designed for more detailed, small-scale studies.

Some of the problems leading up to this investigation have been previously outlined (Cassie, 1957). The majority of plankton organisms are not randomly distributed in space, but exhibit pronounced aggregation of individuals. This aggregation may still be evident, even when the spacing between samples is relatively small, say one metre or less. Some of this aggregation may be attributed to causes which are primarily biological (competition, predation, gregariousness, etc.). There is, however, some indication that sea water, even in the open sea, is not entirely homogeneous, but may present small fluctuations in space of temperature and other physical properties. These may induce tactile movements of organisms along thermal and other gradients toward

regions of slightly more favourable environment, thus producing aggregations. Some suggestion of this type of behaviour has been produced by Barnes and Marshall (1951). At present the minimum gradient to which an organism may respond is not known, but Bull (1936) has shown that some teleostean fishes show a definite response to temperature changes as small as 0·03° C. Thus, it is not unreasonable to anticipate sensitivity of a similar order in the plankton. It has been shown by Liebermann (1951) that random fluctuations of temperature with an amplitude of 0·1° C or more, and a mean length of about 60cm are of common, if not universal occurrence in oceanic waters. It is probable that oscillations of several different orders of magnitude (both as regards amplitude and length) may be superimposed in the same water mass.

he term "spatial distribution" has been widely used in ecological literature, usually in connection with relatively small-scale patterns of distribution, although the term itself does not imply any particular scale. For the purposes of this paper, it is convenient to define three levels of distribution in terms of the horizontal sample spacing necessary to describe them adequately.

(1) Mega-distribution ($>$ 100 metres).
(2) Meso-distribution (1 to 100 metres).
(3) Micro-distribution ($<$ one metre).

The vertical intervals are left undefined, since the dominant physical changes in this case are gradients rather than random variations, so that rather different problems are involved. However, the one metre limit between meso- and micro-distribution is about the right order for the vertical as well as the horizontal plane.

The above classification is arbitrary and is not intended as a contribution to ecological terminology. Nevertheless, it has a basis of reality in reference to the problems at present under consideration.

Mega-distribution is concerned with the gross pattern of oceanic fauna and climate, and is usually referred to as geographic or regional distribution. One hundred metres is about the greatest horizontal precision in station position that can be achieved and reproduced by normal navigational methods. In the open sea a minimum of about three miles would perhaps be more appropriate. While geographic distribution is, strictly speaking, a spatial distribution, it is not usually referred to as such, and is not considered in the present investigation.

Meso-distribution is the pattern usually encountered and sometimes empirically described in investigations of sampling variation. This is the spatial distribution usually referred to in the plankton literature. The minimum sampling interval of one metre is partly a practical one dictated by the limitations of ship manoeuvring. There is, however, a more fundamental basis, in that it is necessary for statistical analysis to have a certain minimum number, say 50, organisms per sample of each species being studied.

While numbers of organisms can vary enormously, under average temperate conditions the mean number of the commonest zooplankton species in a body of water may have a numerical density in the order of one per litre, or 1000 per cubic metre. By the time the fourth or fifth commonest species is reached the mean number per cubic metre will probably be reduced to about 50. Thus, for zooplankton studies it is desirable to take water samples with a volume not much less than one cubic metre, which automatically limits the minimum sampling interval to about one metre.

The Liebermann 60cm pattern of temperature fluctuation falls within the metre interval, and an investigation of its influence on plankton will require sample intervals and volumes in the order of 10cm and 1 litre respectively. The zooplankton population will be difficult to assess statistically at this level, since it is well known that as the mean is progressively reduced below unity, the distribution of counts rapidly approaches Poisson, even in samples from highly aggregated populations. However, the phytoplankton and the various micro-organisms commonly classified as nannoplankton often occur in far greater numbers than one per litre and thus may provide a convenient field for the investigation of micro-distribution.

The present technique is designed for the study of meso-distribution, more particularly of the zooplankton. Its most important feature is the ability to obtain physical observations and biological counts simultaneously from identical parcels of water. It is designed to extract the plankton from a series of equal volumes of water, collected at intervals of one metre or more, at the same time recording two physical properties of the water, temperature, and salinity. This is regarded as a first step only in the study of spatial distribution, and it is hoped that the information so gained will lead to the development of means for investigating the micro-distribution.

Requirements of the Technique

The Plankton Sampler

This apparatus must be capable of sampling without any form of progressive bias. Most net-type instruments are unsuitable, since they tend to become clogged, and thus to filter a diminishing quantity of water for successive tows. A possible exception would be an instrument such as the continuous plankton recorder (Hardy, 1939) in which the filtering material is continuously renewed. However, the problem of clogging is readily overcome by the use of a plankton pump. This enables an accurate measure to be taken of the volume of water filtered and at the same time makes this water available at the surface for physical determinations, thus reducing the need for sub-surface sensing elements.

It is, of course, possible that there is a variation, either random or progressive, in the avoidance reaction of organisms to the pump intake. The same objection applies to almost any type of sampling equipment that can at present be conceived.

It is also necessary for the technique of filtering to be substantially free from mechanical errors due to loss or contamination by organisms adhering to parts of the apparatus. Such errors may be minimised by care in design of the filter holder, and by using a fresh filter for each sub-sample.

Plankton Counts

A special requirement arises from the relatively high degree of accuracy necessary. In geographical studies, heterogeneity of spatial distribution is usually considered purely as a source of error, which is estimated empirically (if at all). The error is, in fact, usually so great that accuracy in counting becomes an unwarranted labour. In the present instance, however, it is the source of the error itself that is being studied in detail, and considerably greater accuracy in counting is not only warranted, but essential.

Since sample volumes are to be reduced to a minimum, it is essential that organisms be completely enumerated (rather than by sub-sampling), so that the maximum information can be extracted.

Physical Variables

The problem of correlating pelagic organisms with their environment is in one respect easier than in some other ecological fields. Most physical properties of sea water are amenable to numerical estimation (cf. the difficulties of assessing cover, topography, etc., as affecting terrestrial or benthic organisms). These estimations may, however, involve considerable time and labour. It is most desirable that the physical pattern should be known *at the time of sampling* so that appropriate adjustments to the experiment may be made without delay. Thus, rapid and preferably continuous recording techniques are necessary, even if they involve some compromise between those properties most significant biologically and those most readily determined. Fortunately, techniques do exist which are adaptable to automatic recording of a fairly representative selection of the key physical properties, notably temperature, salinity, dissolved oxygen, pH, depth, light-penetration, and transparency.

The degree of accuracy required in these determinations can not readily be predicted. For temperature and salinity, the two factors at present under consideration, the fiducial limits of $\pm 0{\cdot}02^{\circ}$ C and $\pm 0{\cdot}02‰$ respectively have been adopted. These can be achieved without undue elaboration of instrument design, and the temperature limit

is slightly lower than the minimum temperature change found to evoke a response in fish by Bull (1936). Emphasis is rather more on relative than absolute accuracy.

Spacing of Samples

Where physical inhomogenities are already known to exist from conventional hydrological investigations, the sampling interval will present no problem since it will be within the range of normal ship manoeuvring. Nevertheless, it has become evident that patterns may be present requiring the very closest of sampling to detect them.

THE PLANKTON PULP

The pump (Fig. 1) is a portable 1½ in. (hose diameter) petrol-driven centrifugal model, with a maximum delivery rate of approximately 200 litres (44 gallons) per minute with a 15 ft suction head. Measurements

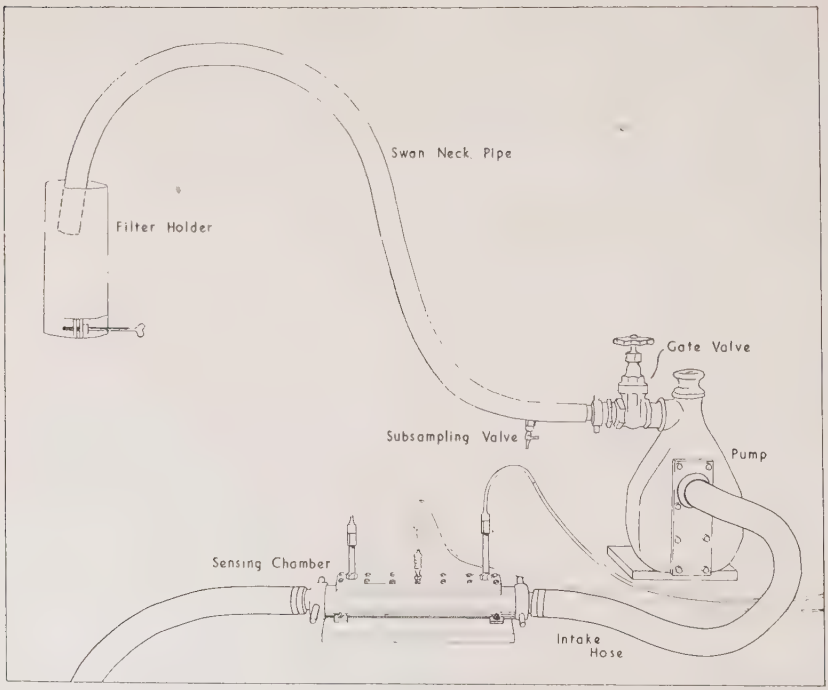

FIG. 1.—The plankton pump assembled for operation.

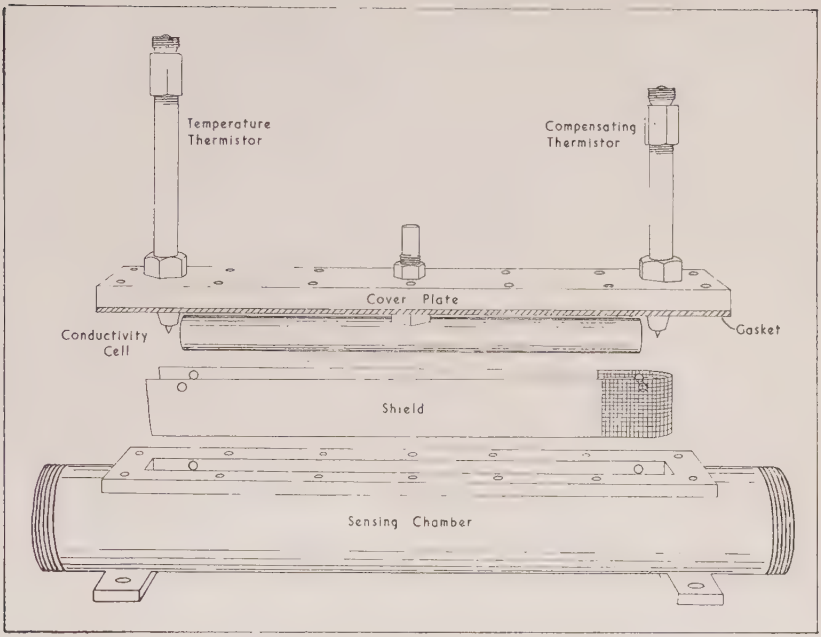

FIG. 2.—Exploded view of the sensing element chamber.

have shown that there is no significant variation in the rate of flow, provided the motor has been thoroughly warmed up. To reduce metallic contamination, a pump has been chosen with a non-corrosive aluminium alloy body and phosphor-bronze impellor.

The intake hose is armoured for the first 40 ft, but beyond this one or two 60 ft lengths of ordinary 2-ply rubber and canvas hose are added to reach greater depths. Since these are entirely immersed, they are not subject to sufficient pressure to cause collapse. There is a break in the armoured hose 3 ft from the pump to allow for the insertion of a sensing element chamber which is shown in exploded view in Fig. 2. This allows a conductivity cell and thermistors to be placed in the intake hose line. Tests have shown that the change in temperature of water between hose intake and surface is less than 0·02° C.

A shield of sheet brass with a wire gauze strainer (12 meshes per inch) protects the sensing elements from damage or blockage. The pump output may, if required, be reduced by a gate valve. The usual delivery hose has been replaced by a rigid "swan-neck" of $1\frac{1}{2}$ in. copper pipe, with an outlet inclined about 20° from the vertical. This pipe may be directed over the ship's rail and the water discharged outboard. On one side of the outlet are two brass studs to which the filter-

holder may be attached. The latter is a cylinder 12 in. x 5 in. of 16-gauge brass sheet, with two "inverted keyhole" slots which engage the studs on the outlet pipe. The filters are 6 in. squares of bolting cloth, one of these being held over the bottom of the holder by a 22-gauge brass strap which may be tightened with a wing-screw. The 20° inclination of the outlet ensures that the water swirls continuously around the walls of the filter holder, washing down any adhering plankters. Two filter-holders are used alternately. Any type of filtering cloth could be used, but for most purposes, either a 6xx or a 12xx blothing cloth has been found convenient. The details of these cloths when new are so shown in Table 1.

TABLE 1.

Cloth grade	Meshes per inch	Meshes per cm	Mean aperture width	Filtering area (%)
6xx	74	29	0·22 mm	41
12xx	125	49	0·11 mm	29

When the coarser grade of filter is used, water generally passes straight through the mesh without building up an head in the cylinder, except when salps or other large organisms are abundant. With the finer mesh there is some tendency for clogging when diatoms are plentiful, but the depth of the cylinder has been found adequate to cope with the flow for filtering times of at least one minute.

At the base of the "swan neck" is an $\frac{1}{8}$ in. sub-sampling tap for taking small aliquots from the main volume of water, either for special physical determinations or for phytoplankton counts.

Prior to operation, the pump is run for about 10 min. to warm the motor. While sampling is under way, the filter holder is changed at intervals of (usually) 1 min., a fresh filter being used for each sample. Used filters, together with the adhering plankton are preserved entire in separate 4 oz jars of 5% formalin. Usually at least 50 samples are taken in any one series. The attachment of filter holder to outlet is such that changes of filters can be effected accurately to less than 1 sec. (i.e., with a volume variation in 1 min. of less than 2%). A complete cycle of filter changing can be comfortably carried out in 1 min., which is the standard sampling interval, filtering about 200 litres. This is $\frac{1}{5}$ of the suggested ideal volume of 1000 litres, but has proved to be a satisfactory compromise. It would be almost impossible to maintain ship position within 1 metre for as long as 5 min.

A series of samples may be taken either in a vertical or a horizontal plane. In the vertical direction it is a relatively simple matter to raise or lower the hose as required. In the horizontal plane the ship can be manoeuvred by normal means, but in order to preserve a relatively

short distance between samples it has been found convenient to let the ship drift with the wind (Barnes and Marshall, 1951). While the speed of drift is not controllable, it is usually fairly constant and much slower than could be achieved under power. Another alternative is to anchor in a weak tidal stream and allow the water itself to move past the sampling station. In either instance, a suitable float placed in the water indicates the distance between samples.

PLANKTON COUNTING

The sample from each jar is transferred to a plastic bowl, using a wash bottle to remove any plankters adhering to the filter square. After reduction in volume (by settling and siphoning) to about 30cc, the sample is transferred to a perspex trough mounted on a long stage in such a way that it can be moved longitudinally through the field of a stereo-binocular microscope. The trough is 28cm long, 2·2cm deep, and 1cm wide at the bottom, with sides sloping outwards at 45° so that the surface meniscus is outside the microscope field. The bottom is graduated at intervals of 0·8cm, making a series of rectangles 1·0 x 0·8cm, each of which is just covered by the field of view. Counts of the more common organisms are recorded on a Swift point counter (without the integrating stage). The counter has been modified by incorporating a repeating relay which allows each dial to operate automatically as long as the key is held down. Each digit added gives an audible click and the relay can be adjusted between speeds of 3 and 7 per second.

THE TEMPERATURE RECORDER

Recorders or indicators employing thermistors (or negative-temperature-coefficient resistors) have been frequently described (e.g., Mclean, 1954) so that little discussion of the present instrument is necessary. A simple Wheatstone bridge circuit is used. The power supply is a $1\frac{1}{2}$ volt dry cell with dropping resistances to give an input voltage of 0·25 volts to avoid heating the thermistor. The thermistor is Philips type 138.320.05 P/IK (1000 ohm at 20° C) which is cast in Araldite casting resin D inside a $\frac{1}{2}$ in. brass tube with about $\frac{1}{4}$ in. of the sensing tip projecting. The off-balance bridge current is recorded on an electronic strip-chart potentiometer (Honeywell-Brown) with a range of 0 to 10 milliovolts. Other channels are available on the same instrument to record salinity, depth, etc. Three ranges are available: 15° to 25° C, 10° to 20° C, and 5° to 15° C. The instrument is sensitive to $\pm$ 0·02° C and linear to $\pm$ 0·03° C. Provided initial calibration is carefully carried out, absolute accuracy is of the same order. The time constant is sufficiently small to allow the instrument to respond fully to temperature changes in less than 1 sec., which is more than adequate for the purpose required.

THE SALINITY RECORDER

Discussion

Of the various methods available for determining salinity those based on electrical conductivity appear the most promising for continuous recording. A summary of recent techniques has been made by Cox (1955). The three main difficulties arise from polarization, electrode fouling, and the need for temperature compensation.

Polarization is a problem common to all conductivity measurements in electrolytes and may usually be reduced to a sufficiently low level by using a relatively high frequency alternating measuring current, by platinizing electrodes, and by increasing the cell constant to as high as a figure as possible.

Fouling due to organic or other suspended or dissolved matter in natural waters is a problem not normally encountered in the electrochemistry laboratory and has less predictable effects. Three solutions are available (which are, incidentally, also precautions against polarization). Harwell (1953, 1954) and Harwell and Druce (1954) have used external electrodes and a radio frequency current relying on capacitance to carry the current through the glass cell wall. Esterson (1957) employs a toroidal transformer system to induce a current in a cell without electrodes. While these two methods appear to approach the ideal solution, they are complex, both mechanically and electronically. Since facilities for instrumentation were limited, it was decided to resort to the rather simpler solution of employing a conventional cell which was chemically cleaned or replatinized at frequent intervals (Hamon, 1955; Scheimer and Pritchard, 1957).

Since conductivity is dependent on temperature as well as salinity, some means is necessary to compensate for temperature changes. This may, of course, be carried out by subsequent calculation, or even by a servo-mechanism (Jacobson, 1950), but both methods are clumsy.

The simplest form of automatic compensation is to incorporate a reference cell containing water of known salinity in an adjacent arm of a Wheatstone-type bridge (Wenner, Smith, and Soule, 1930), both cells being kept at the same temperature. This is unsuitable for continuous recording owing to the time lag in equalizing temperatures, though it is conceivable that a reference cell of very small dimensions could be so used. Dorrestein (1954) has replaced the reference cell by a thermistor which has a much more rapid temperature response and approximates sufficiently well to the temperature-resistance characteristic of sea water. Because of its simplicity, both in construction and operation this method has been chosen for the present instrument.

Design, Calibration, and Operation

The design is basically similar to an instrument described by Hamon (1956), but has been modified for the purpose of continuous record-

ing. The conductivity cell is a straight glass tube, 9 in. long and about 0·25 in. internal diameter, with three annular platinized platinum electrodes fused to the inner surface at approximately 4 in. intervals along its length. The two outer electrodes are connected together and earthed, so that together with the centre electrode they form in effect two similar cells connected in parallel, the whole having a cell constant of $10cm^{-1}$ approximately. The cell is mounted with Araldite D in a chromium-plated brass tube with a threaded nipple projecting at right-angles from the centre, carrying a concentric push-on type microphone plug at its extremity for electrical connection to the electrodes (Fig. 2). The compensating thermistor is a Stantel type F.2200, which has a resistance of about 200 ohm at 20° C and is mounted in similar manner to the temperature-recording thermistor. A resistance of suitable value (about 100 ohm) is connected in series to the thermistor, to match its temperature co-efficient to that of the cell. A twin-core shielded microphone cable connects cell and thermistor to the measuring circuit, so that they form adjacent arms of a Wheatstone bridge.

The measuring instrument is a "direct reading measuring" (D.R.M.) bridge (Philips G.M. 5536/01). This contains a 4 kc/s oscillator supplying current to the bridge, and an amplifier and phase-sensitive detector which convert the off-balance bridge current to direct current in a suitable voltage range for recording on the strip-chart recorder. Several small modifications have been made to the D.R.M. bridge (in such a manner that the bridge may be returned to its original condition and purpose by a single switch installed in the back). In order to permit greater latitude in balancing sensing cells and thermistors of differing resistance the ganged variable condensors, which normally occupy two arms of the Wheatstone bridge, are replaced by two wire-wound non-inductive resistances. A resistance placed in series with the oscillator output reduces the voltage across the bridge to about 25 millivolts. This ensures that the power dissipation in the thermistor is insufficient to raise its temperature by more than 0·005° C. A shunt resistance across the output terminals is necessary to match the impedance of the D.R.M. bridge to that of the potentiometer.

Three ranges are available: 33 to 37‰, 30 to 34‰, and 27 to 31‰ and provision is made to substitute a fixed resistance and a resistance box for thermistor and cell respectively for calibration purposes. A variable resistance in one arm of the Wheatstone bridge is employed for zero adjustment, while a fine adjustment control on the amplifier gain of the D.R.M. bridge is used to adjust the span.

For calibration, a single sample of sea water of known salinity is required. Cell and thermistor are immersed in this sample in a chromium-plated brass trough, which is itself immersed in a constant temperature bath at 20 ± 0·5° C. As soon as a steady record is obtained on the potentiometer the fixed resistance (equal to the thermistor arm at 20° C) and resistance box, are substituted in the circuit, and adjusted to give the same reading as before. The resistance

shown on the box is then that of the cell at 20° C and the salinity of the reference sample. From these figures it is then possible, from the tables of Thomas, Thompson, and Utterback (1934) to compute appropriate resistances for the zero of the required range, and for one other point about midway on the scale. By setting these in turn on the resistance box and at the same time adjusting respectively the zero and span controls, the salinity scale can be matched to the strip chart. Interpolation of other points may be made by similar means, but is scarcely necessary as the scale is linear to within the accuracy of the instrument for any span up to 3‰.

To operate, the sensing elements are assembled in the sensing chamber as indicated in Figs 1 and 2, and the pump is run for about 10 min. to allow the electrodes to become thoroughly wet before recording is commenced. An occasional sample taken from the sub-sampling tap on the pump allows a subsequent calibration check to be made in the laboratory.

Under laboratory conditions the salinity recorder has operated with relative and absolute accuracies of ± 0·02‰ in the 33 to 37‰ range. In the field a similar standard can be achieved for periods of at least an hour but over longer periods absolute calibration varies within wider limits. Experience during calibration in the laboratory suggests that, under field conditions, any change in salinity would be registered within at least 10 sec. and probably much less than this, provided it was not accompanied by a temperature change greater than 2° C.

Discussion and Preliminary Results

Of the three main components of the technique, plankton collecting and temperature recording have been found highly effective and capable of operation with the minimum of trouble under field conditions. It is necessary, however, to be constantly on the watch for inconsistencies in salinity recording due to electrode fouling.

Data collected will be published later, and for the present it is necessary only to quote sufficient details to indicate the type of phenomena likely to be revealed.

Three types of correlation are likely to occur in any one set of samples: between counts of different species; between species' counts and physical variables; and serial correlations between counts of any one species.

Between species, positive correlations are the most common and usually the most pronounced, though significant negative relationships do occur. As many as five different species in a single series of samples have been found linked by high positive correlations*.

*Apparent positive (but not negative) correlations of this type could be due to fluctuations in the volume of water pumped. However, except in a few borderline cases, the implied fluctuations in pumping rate would be so large as to be mechanically impossible.

Species-to-salinity correlations appear to be rather more common than species-to-temperature. When the latter do occur they are usually associated with relatively abrupt discontinuities rather than random fluctuations in temperature.

With any one species there is often a marked tendency for each sample to bear a closer numerical resemblance to its nearest neighbours than to those samples further removed (a common feature of many natural phenomena). The correlogram of such a series decays rapidly after the first oscillation, indicating a random rather than a regular periodicity. The average interval between aggregations (i.e., one complete oscillation of the correlogram) has usually been found to be of the order of 50 metres. However, this particular distance is a function of the sampling technique rather than of the population itself, and there is evidence to suggest that, in the same population, aggregations of several different orders of magnitude may be superimposed. In fact, experiments using another technique have revealed a marked departure from randomness in diatom populations which is still evident at sampling intervals of only 10cm, a phenomenon which may be related to the Liebermann 60cm temperature pattern.

The principal application of the technique is to the study of inshore plankton populations where relatively gross inhomogeneities of the physical environment occur. These conditions will produce an exaggerated form of aggregation, and thus form a suitable field in which to discover some of the fundamental principles which may be later applied in the study of micro-distributions and open sea phenomena.

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REFERENCES

BARNES, H.; MARSHALL, S. M., 1951: On the Variability of Replicate Plankton Samples and some Applications of "Contagious" Series to the Statistical Distribution of Catches Over Restricted Periods. *J. Mar. biol. Ass. U.K. 30* : 233-63.

BULL, H. O., 1936: Studies on Conditioned Responses in Fishes. Pt. VII. Temperature Perception in Teleosts. *J. Mar. biol. Ass. U.K. 21* : 1-27.

CASSIE, R. M., 1957: The Sampling Problem, with Particular Reference to Marine Organisms. *Proc. N.Z. ecol. Soc. 4* : 37-9.

COLLIER, A., 1957: Gulf-II Semiautomatic Plankton Sampler for Inboard Use. *Spec. sci. Rep. U.S. Fish Wildl. Serv. 199.*

COX, R. A., 1955: Essay Review. Recent Work on the Measurement of Salinity by Electrical Means. *J. Cons. int. Explor. Mer. 20* : 306-9.

DORRESTEIN, R. R., 1954: Een Registrerende Electrische Zoutgehalte-en Temperatuurmeter voor Gibruik op Zee. *Kon. Nederlands Meteor. Inst., Medd. in Verhand. 59* : 387-403.

ESTERSON, G. L., 1957: The Induction Conductivity Indicator (I.C.I.). A new method for conductivity measurements at sea. *Chesapeake Bay Inst. Tech. Rept., 14.*

HAMON, B. V., 1955: A Portable Temperature-chlorinity bridge for Estuarine Investigations and Sea Water Analysis. *J. sci. Instrum. 33* : 329-33.

HARDY, A. C., 1939: Ecological Investigations with the Continuous Plankton Recorder. Object, Plan, and Methods. *Hull. Bull. Mar. Ecol. 1* : 1-57.

HARWELL, K. E., 1953: Radio Frequency Salinity Instrument Model C1. *Agric. Mech. Coll. Texas, Dep. Oceanog. Tech. Rep. 3.*

————, 1954: Radio Frequency Salinity Instrument Model E. *Agric. Mech. Coll. Texas, Dep. Oceanog. Tech. Rep. 4*

————; DRUCE, A. J., 1954: Wein Bridge and Twin T. Salinity Instruments. *Agric. Mech. Coll. Texas, Dep. Oceanog. Tech. Rep. 5.*

JACOBSON, A. W., 1950: An Instrument for Recording Continuously the Salinity, Temperature, and Depth of Sea-Water. *Int. hydr. Rev. 27* : 107-22.

LIEBERMANN, L., 1951: Effect of Temperature Inhomogeneities in the Ocean on Propagation of Sound. *J. acoust. Soc. Amer. 23* : 563-70.

MCLEAN, J. A., 1954: A Method for Constructing Direct Reading Thermistor Thermometers. *J. sci. Instrum. 31* : 455-7.

SCHIEMER, E. W.; PRITCHARD, D. W., 1957: The Chesapeake Bay Institute Conductivity-temperature Indicator (CBI—CTI). *Chesapeake Bay Inst. Tech. Rep 12.*

THOMAS, B. D.; THOMPSON, T. G.; UTTERBACK, C. L., 1934: The Electrical Conductivity of Sea Water. *J. cons. Int. Explor. Mer. 9* : 28-35.

WENNER, E.; SMITH, E. H.; SOULE, F. M., 1930: Apparatus for the Determination Aboard Ship of the Salinity of Sea Water by the Electrical Conductivity Method. *J. Res. nat. Bur. Stand. 5* : 711-32.

CONTRIBUTIONS TO THE QUATERNARY HISTORY OF THE NEW ZEALAND FLORA

I. AUCKLAND ISLAND PEAT STUDIES

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Summary

Peat stratigraphy and peat vegetation were studied for ten days over a small area of Auckland Island in the vicinity of Port Ross. The area included a plateau about 200 ft above sea-level, a steep scarp on the northern side of the plateau, and a raised bog in a shallow valley near the base of the scarp. The peats examined are part of the blanket bog complex which covers the surface of the Auckland Islands to varying depths. The plateau bog and the bog in the shallow valley are characterized by the presence of cushion plants such as *Oreobolus pectinatus*. The scarp carries *Metrosideros umbellata* (southern rata) forest.

From these areas samples were collected for pollen analysis, and the results from four profiles are presented. No detailed correlation with published pollen analyses from the southern hemisphere has been made, but the consistent maximum of *Metrosideros* pollen forms a basis for dividing the profiles into three stages, and it is suggested that the *Metrosideros* maximum is synchronous with the warm, forest period which obtained in New Zealand between the seventh and fourteenth centuries.

Brief notes are given on some pollen types, and the first appearance of Centrolepidaceae pollen in New Zealand peats is recorded. A note on long-distance transport of pollen discusses the presence of pollen of *Podocarpus*, *Dacrydium*, and *Nothofagus* in the profiles. These genera do not occur on the Auckland Islands.

The absence of living *Sphagnum* and the fact that no traces of *Sphagnum* were found in the profiles is recorded.

Introduction

The subantarctic islands present many unsolved botanical problems. The palynological approach to these problems has been neglected, although Hafsten (1951) published pollen results from Tristan da Cunha and Harris (1953) described the results of one profile from the Snares Islands. In addition, Erdtman (pers. comm.) examined material from the Auckland Islands thirty years ago.

Studies in peat stratigraphy also have been neglected. Taylor (1955), however, described Macquarie Island peat in some detail, and Aston (1909) investigated subantarctic island peat as soils. Cranwell (1953b)

presented a classification of New Zealand peatlands, and included the subantarctic area. This has been the only attempt to define peats from this region.

The author was a member of an expedition which worked on the Auckland Islands for ten days in November 1954. These islands lie between 50° 26′ S and 165° 52′ and 166° 22′ E and are some 200 miles south-south-west from the south coast of the South Island of New Zealand. The expedition, sponsored by the Department of Scientific and Industrial Research, was led by Dr R. A. Falla, Director, Dominion Museum. Transport to the islands was arranged by the Navy Department in H.M.N.Z.S. *Tui*, which ship was carrying a relief to the meteorological station on Campbell Island.

The main tasks undertaken by the author were investigation into the peat, the peat vegetation, and the collection of samples for pollen analysis. Representative collections of the flora were made also, mainly

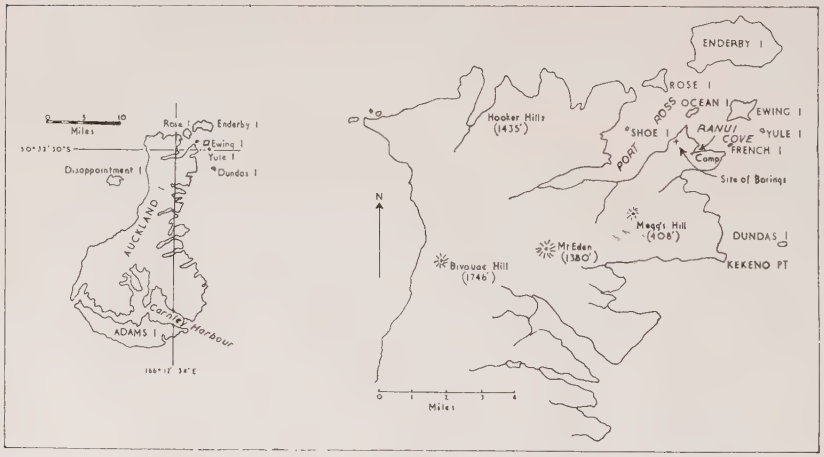


FIG. 1.—Sketch map of Auckland Island and detail of the Port Ross area.

by Dr J. B. Hair, Botany Division, D.S.I.R., who was able to collect extensively on French Islet, Ocean Island, and Ewing Island, in addition to collecting at various points in Port Ross, and on Adams Island at the southern end of the island group (Fig. 1).

Because of the limited time available, palynological work was restricted to a small area about one mile from Ranui Cove in Port Ross. As there are descriptions of the Auckland Islands available (Chilton, 1909; Falla, 1948) no details are given in this paper except for a

brief description of the locality investigated. The area includes a gently sloping plateau about 200 ft above sea-level. To the south the plateau falls away into a wide valley. The northern edge of the plateau is bounded by a conspicuous scarp 100 ft high. A shallow valley, in which there is a raised bog, lies between the scarp and a low ridge which falls away to the coast (Fig. 2).

The plateau is about half a mile long and four to eight chains wide. Along the main axis the plateau slopes gradually towards the north-east. Along the short axis the bog is convex. At the northern edge there is an almost vertical slope four to six feet high rising from the scarp. From here the bog surface rises, steeply at first, towards the crown which is quite flat. From the crown the southern slope is initially gradual, but rapidly increases as it falls into the wide basin already mentioned. Superimposed on the sloping surfaces are low hummocks

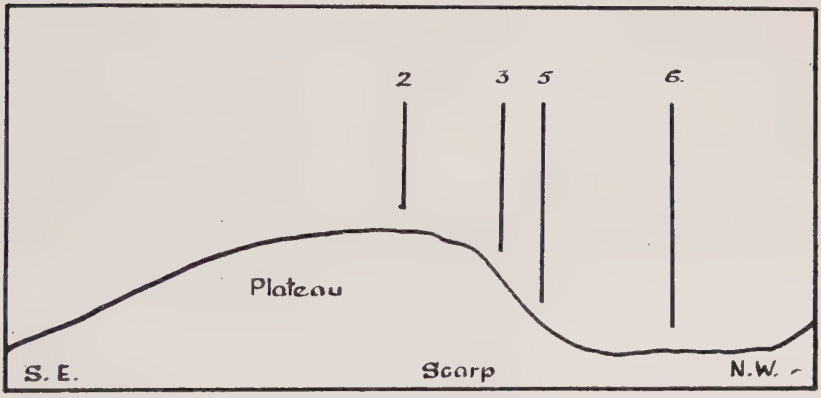


FIG. 2.—Diagrammatic cross-section of the peat areas investigated. The location of the profiles from which the pollen diagrams are constructed is indicated.
Drawn by A. A. Sutherland.

and hollows, commonly of considerable area. These have been formed by the cushion-forming plant *Oreobolus pectinatus* Hook. f. There are also larger mounds formed by *Metrosideros umbellata* Cav. (southern rata) and *Dracophyllum longifolium* R. Br. Smaller mounds on the steeper, better drained slopes have been formed by erosion. On the lower southern slope there is a mosaic of *Metrosideros umbellata*, shrubs and tussock-grass (Fig. 3), the tussock-grass giving the impression of tortuous roadways through the shrubs (Cockayne, 1909).

FIG. 3.—Looking down from the southern slope of the plateau bog. Note the pattern made by *Metrosideros umbellata* Cav. and *Danthonia antarctica* Hook. f.
Photo: *N.T.M.*

The raised bog in the valley is covered by a complex of cushion plants, and the scarp and lower lying terrain generally, by *Metrosideros* forest.

The area is covered by peat varying in depth and composition. Peat profiles were examined on the plateau, at the northern edge of the plateau, in the forest near the base of the scarp, and in the raised bog in the valley.

The areas investigated fall into two groups:

(1) The bogs, i.e., the plateau bog and the raised bog in the shallow valley.

(2) The scarp, dominated by *Metrosideros* forest.

PEAT VEGETATION AND PEAT PROFILES

Vegetation

THE PLATEAU BOG

Crown of the bog: *Oreobolus pectinatus* formed a complex of hummocks and hollows on the crown of the bog and on the gentler slopes on the north and south sides. One *Oreobolus* hummock, 3 ft across and 6 in. high had the following species growing on it:

Phyllachne clavigera F. Muell.
Astelia subulata (Hook. f.) Cheeseman
Gentiana cerina Hook. f.
Danthonia antarctica Hook. f.
Dracophyllum sp.

Additional species growing on other hummocks were:
Schizaea fistulosa Labill, var. *australis* (Gaud.) Hook. f.
Astelia linearis Hook. f. var. *linearis*
Coprosma pumila Hook. f.
Metrosideros umbellata Cav.

In the hollows between the hummocks were large patches of *Gaimardia ciliata* Hook. f. After rain the hollows held shallow pools of water (Fig. 4).

FIG. 4.—Water lying in hollows at the crown of the plateau bog after rain. The hummocks are mainly of *Oreobolus pectinatus* Hook. f., note also *Dracophyllum* sp. and *Danthonia antarctica* Hook. f.

Photo: N.T.M.

Many of the hummocks were disintegrating, but others were forming in hollows. The incipient hummock is initiated by the vigorous growth of *Gaimardia ciliata* which is succeeded by the cushion-forming *Oreobolus pectinatus*. *Metrosideros* may germinate on the cushion so formed. When it reaches the form of a shrub about three feet in height, it

suppresses the *Oreobolus* until a hollow is again formed. Such hollows are commonly overgrown from the edges by the vigorous growth of *Oreobolus*. In this way a mound is again formed through the top of which the *Metrosideros* protrudes (Fig. 5). Such hollow and hummock cycles were seen in all stages of development. This phenomenon may represent an early stage in the formation of larger *Metrosideros* mounds scattered over the bog surface.

FIG. 5.—*Oreobolus pectinatus* Hook. f. encroaching on to, and forming a hummock around, *Metrosideros umbellata* Cav. which is growing in a hollow.
Photo: N.T.M.

The following species were growing on one of the larger mounds:

Metrosideros umbellata Cav. (*c* 3 ft high)
Suttonia divaricata Hook. f.
Cassinia vauvilliersii Hook. f.
Coprosma foetidissima Forst.
C. cuncata Hook. f.
Dracophyllum longifolium R. Br.

Under the dense canopy of shrubs there was little ground cover, but in patches within the clump were:

Oreobolus pectinatus Hook. f.
Cyathodes empetrifolia Hook. f. (seedlings)
Metrosideros umbellata Cav. (seedlings)
Dracophyllum sp.
Coprosma pumila Hook. f.

FIG. 6.—Dead shrubs of *Metrosideros umbellata* Cav. on the northern slope of the plateau bog. Cushions of *Oreobolus pectinatus* Hook. f. are visible in the foreground.

Photo: N.T.M.

The northern slope: The northern slope was much drier than the crown of the bog. On this slope there were large mounds of *Oreobolus* and larger and denser tussocks of *Danthonia antarctica*. Clumps of shrubs were more numerous and in addition there were many dead shrubs of *Metrosideros umbellata* (Fig. 6).

The southern slope: The vegetation of the southern slope consisted of a complex of hummocks and hollows. On steeper slopes erosion was evident, and in some places disintegrating hummocks of *Oreobolus pectinatus* were devoid of living plants. The peat was dry and much affected by the frequent winds. In less severely eroded parts (Fig. 7) *Oreobolus* still survived on crumbling hummocks on which were growing:

Cyathodes empetrifolia Hook. f.
Phyllachne clavigera F. Muell.
Dracophyllum sp. (seedlings)
Danthonia antarctica Hook. f.

FIG. 7.—Eroding hummocks on southern slope of the plateau bog.
Photo: *N.T.M.*

These plants also grew into the hollows. In many hollows, however, only the dead remains of plants were found.

BOG IN VALLEY

The vegetation of this bog was similar to that of the plateau bog with *Oreobolus* mounds, *Danthonia antarctica* and stunted patches of shrubs. This bog had fewer plant communities than the plateau bog, and peat formation was not so active. *Metrosideros* forest was slowly encroaching upon the margins.

SCARP

At the edge of the scarp and the plateau bog there was a mosaic of tussock grass (*Danthonia antarctica*) and shrubs. In one such *Danthonia* area there were a few plants each of the following species:

Dracophyllum longifolium R. Br.
Suttonia divaricata Hook. f.
Cassinia vauvilliersii Hook. f.
Nothopanax simplex Seem.
Cyathodes empetrifolia Hook. f.
Lycopodium varium R. Br.

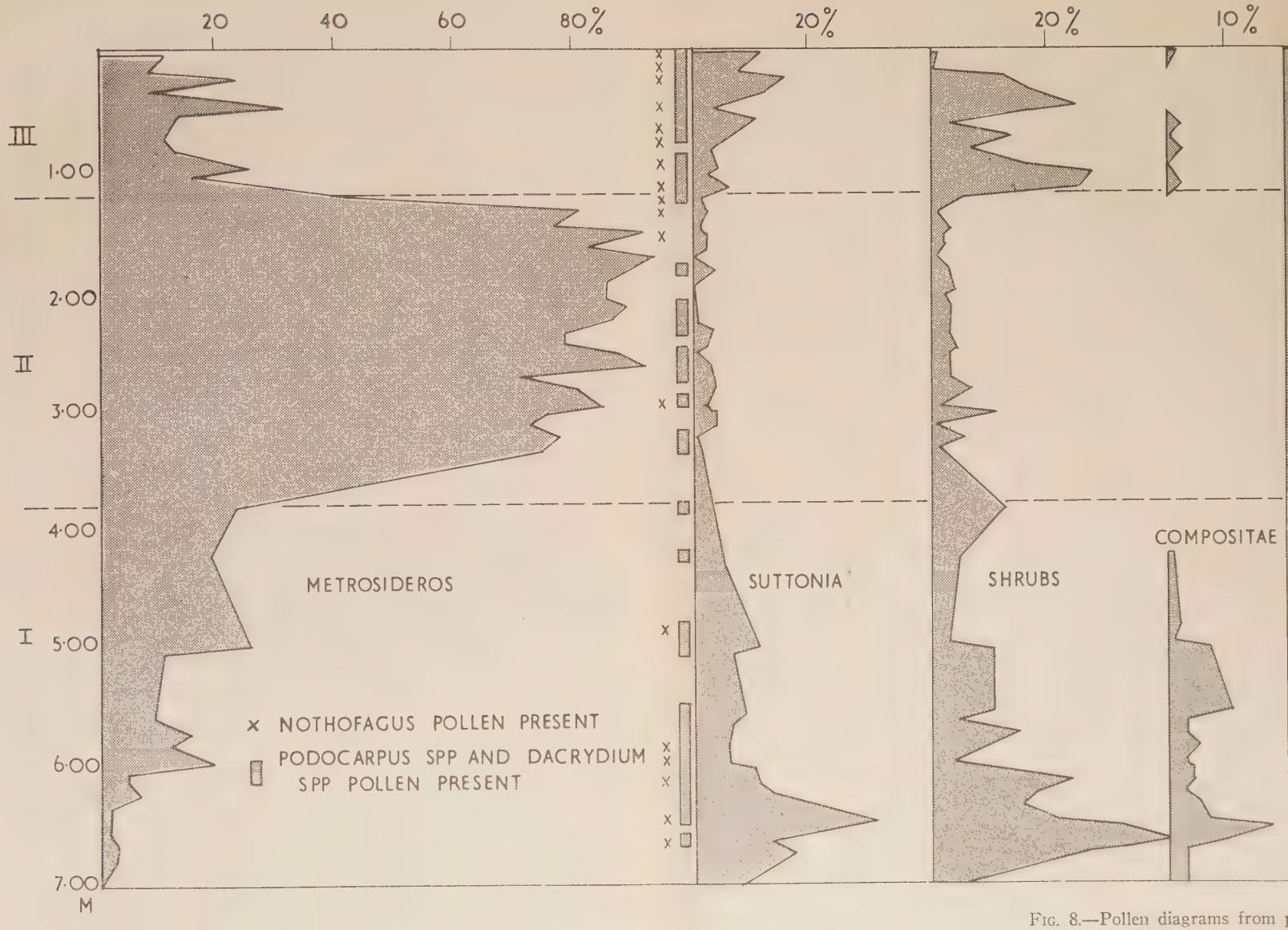
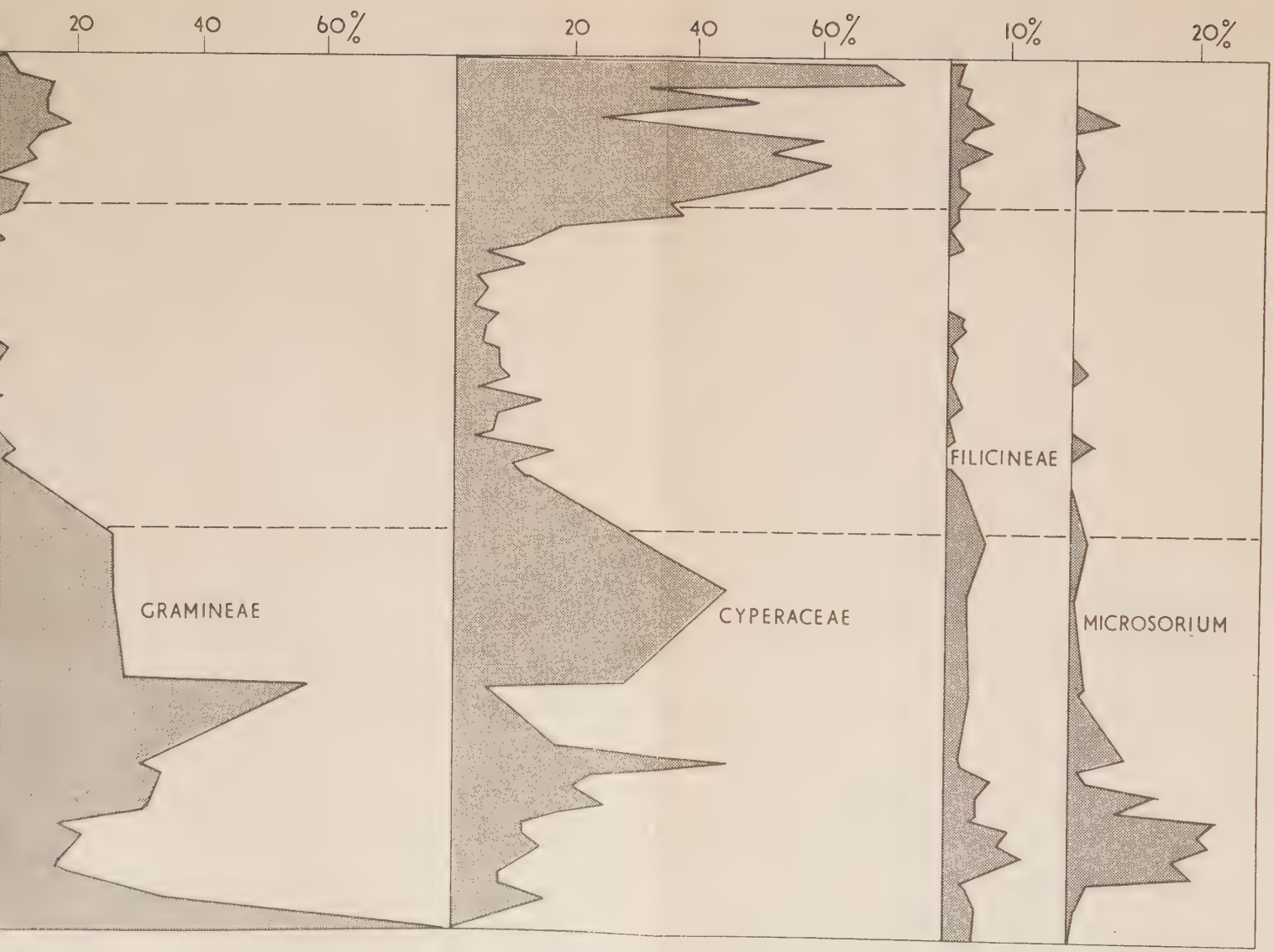


FIG. 8.—Pollen diagrams from



2 (depths in metres).

In one large group of shrubs were:

Metrosideros umbellata Cav. (up to 4 ft high)
Dracophyllum longifolium R. Br. (up to 6 ft high)
Suttonia divaricata Hook. f.
Hebe sp.
Nothopanax simplex Seem.
Cassinia vauvilliersii Hook. f.
Danthonia antarctica Hook. f.

The ground layer included:

Cyathodes empetrifolia Hook. f.
Coprosma cuneata Hook. f.
C. foetidissima Forst. (seedlings)
Schizaea fistulosa Labill. var. *australis* (Gaud.) Hook. f.

On the scarp the *Metrosideros* ranged in height from 20 ft at the base to 6 ft at the summit. On the lower slopes there were large mounds on which *Metrosideros* was growing. The gnarled trunks of *Metrosideros* commonly ran along the ground or grew in a horizontal plane just above ground level for some distance before branching upwards. This characteristic was a striking feature of the forest (Cockayne, 1909, 1928).

Peat Profiles

THE PLATEAU BOG

The thickest peat is found in the central area and the shallowest near the northern side of the plateau. Main features of the plateau peat are the great depth (approximately 8m) of brown, decomposed peat with varying quantities of grass, and wood fragments, and a shallow layer of mineral soil overlying rock. The location of the profiles is indicated (Fig. 2).

Profile 1: The peat at this location is 7 metres thick and overlies solid rock. It is similar to profile 2, which will be described in detail. It is, however, less decomposed, and contains fewer wood fragments, except in the bottom layer. Plant fragments identified in this profile include *Danthonia* sp. leaf bases, floral remains of *Dracophyllum* sp., and leaf fragments of a dicranaceous moss.

Profile 2: This profile was at the crown of the bog.

Depth (cm)

0- 6 Brown; *Oreobolus* remains; H1
0- 25 Dark-brown; *Oreobolus* fragments; some grass remains; W4, H4*

*The degree of wetness of a peat is indicated by a scale of 5 units of measurement. W1 is a dry peat, W5 a peat from which clear water may be squeezed easily by hand.

The degree of decomposition of plant remains in a peat is indicated by a scale of 10 units of measurement. H1 is a raw, undecomposed peat, H10 a peat in which plant remains are completely decomposed.

25- 75	Dark-brown; fibrous, *Oreobolus* fragments; small pieces of wood; one nutlet of *Scirpus* sp.; leaves of *Dicranoloma* sp.; W5, H6-8.
75-550	Brown; fibrous; many rootlets; recognizable bases of *Danthonia* at various depths; many "chaff" like grass fragments; wood fragments of *Dracophyllum* sp.; leaves of *Dicranoloma* sp.; W3, H8-9.
550-673	Dark-brown; fibrous; wood struck at 646cm; *Drepanocladus* sp. leaves at 575cm; W3, H9.
673-716	Grey-brown; loamy; wood present; H9
716-736	Black; loamy; gritty sand adhering to thread of auger; rock at bottom.

Profile 3: Near the northern edge of the plateau bog the peat was shallower, but no transition to the peat characteristic of the forested terrain was observed

Depth (cm)	
0- 25	Fibrous; *Oreobolus* and *Danthonia* rootlets; H1
25- 50	Red; fibrous; *Danthonia* fragments; some wood; W3, H7.
50-175	Dark-brown; fibrous; many rootlets; a few wood fragments; W3, H7-8.
175-200	Dark-brown; much wood; W3, H8.
200-325	Dark-brown; slightly fibrous; plastic; W2, H9.
325-407	Loamy; plastic; a transition layer.
407-441	Grey peaty loam; rock at bottom.

The Scarp

Profile 4: Close to the abrupt transition from bog to the steep scarp a profile was examined within a small tussock area at the edge of a large clump of *Metrosideros* and *Dracophyllum*. The peat is different from that already described, being darker in colour, drier, and is not fibrous except in the upper layers. The great depths of the plateau were not found.

Depth (cm)	
0- 25	Red-brown, fibrous; wood and rootlets; W2, H8.
25- 55	Red-brown; fibrous; wood remains of *Metrosideros* and *Dracophyllum;* W2, H8.
55-163	Dark red-brown; scattered wood fragments; some rootlets; at 145cm a narrow band of grey mineralized peat present; W2, H9-10.
163-168	Grey; heavily mineralized.
168-180	Dark; plastic; W3, H9-10.
180-200	Black loamy peat and mineral bands intermingled; on auger thread grey mineral soil; solid rock at bottom.

Profile 5: This profile was taken from peat dominated by rata forest close to the summit of a large mound near the foot of the scarp.

Depth (cm)	
0- 15	*Danthonia* remains
15- 46	Dark red-brown; compacted; wood fragments.
45- 48	Root layer.
48- 90	Dark red-brown: wood fragments.
90-115	Dark brown; W4.
115-188	Dark red-brown; wood fragments; W2, H8-9.
188-275	Grey-brown; gritty soil; transition abrupt.
275-330	Sticky, gritty soil, rock at bottom.

RAISED BOG IN VALLEY

Profile 6: The peat is similar in origin to that of the plateau bog. There is a shallow layer of raw peat consisting of *Oreobolus* remains, and beneath, a layer of brown fibrous peat, 325cm thick. Underlying the peat, which was 5 metres thick, there was a grey plastic soil through which the auger penetrated 37cm before resistance was too great for further boring. The peat was highly decomposed and only one identifiable plant fragment, a *Danthonia* leaf base, was detected.

DISCUSSION

Of the areas described in this paper the two raised bog surfaces can receive water only by precipitation as rain, mist, and snow, of which the first two are frequent throughout the year. The plateau bog has been formed as a result of impeded drainage on a gentle slope with precipitation as the only source of water. The deposit of grey plastic soil beneath the peat of the lower bog suggests that this area originally received drainage water from higher levels. Drainage down valley keeps this bog drier than the plateau bog.

The vegetation of the raised bogs is characteristically that of the cushion-forming plant *Oreobolus pectinatus*. On the valley bog the absence of *Gaimardia ciliata*, and the more common occurrence of *Metrosideros* on *Oreobolus* hummocks than on the plateau bog suggests that this bog is drier than the plateau bog. The fact that *Metrosideros* is slowly encroaching from the margins is supporting evidence.

Peat on the scarp (see profiles 4 and 5) has accumulated on a steep slope under a forest cover. On such a slope peat could accumulate only under conditions of high humidity. Its compact nature, combined with the binding action of tree roots would tend to stabilize it. The water supply is from two sources. The greatest volume of water is received as precipitation, but some is derived through lateral drainage from the plateau. Its high degree of decomposition suggests that this is a well drained peat.

Cranwell (1953b) described the subantarctic islands peatlands as

complex blanket bog in which convex, flat, and sloping types occur. The author concurs with this view and believes that the convex peats described in this paper can be identified within the blanket bog complex discussed by Cranwell. The scarp peat is a part of the complex not hitherto described. The climate, characterized by a high humidity and frequent rain and mist, is ideally suited for the development of such zonal peats.

There were few identifiable plant fragments in the peat. Those discovered are recorded in the descriptions of the profiles. In the convex bogs the great thickness of fibrous peat in each profile suggests that environmental conditions had remained constant for a long period of time.

Sphagnum was not found in the present vegetation, nor were *Sphagnum* remains found in the peat samples examined. Cranwell's (1953b) remark on the relatively unimportant role of *Sphagnum* in peat formation in New Zealand in general is thus supported by its absence from the Auckland Islands. Oliver and Sorensen (1951) report that on the Campbell Islands, "from the peat bogs proper . . . there is very little *Sphagnum*." These authors distinguish between "peat bogs proper" and *Sphagnum* bogs"; a distinction which may not be valid.

Pollen Analysis

Samples from profiles 2, 3, 5, and 6 have been examined for pollen. In the upper part of each profile no reliable counts were obtained, so that the pollen curves for all profiles are truncated.

Pollen Types

As the number of living species recorded for the Auckland Islands is small it was hoped to identify accurately most pollen types encountered. This hope was not completely fulfilled. It was not expected that grass or sedge pollen could be identified below the family level, but it was hoped that pollen of other groups could be identified more precisely. Some families, for example Myrtaceae and Myrsinaceae, are represented by only one species. Thus, pollen of *Metrosideros umbellata* and *Suttonia divaricata* were easily recognized.

Of the Compositae genera, *Celmisia* and *Cotula* pollen were readily distinguished. *Pleurophyllum speciosum* Hook. f. is also quite distinct, being characterized by spines 4 to 5μ long. *Pleurophyllum hookeri* Buch. and *P. criniferum* Hook. f. cannot be separated on spine characters (which are much shorter than *P. speciosum*), but their average sizes vary by 5μ. But the spines of these two latter species are similar to those of *Olearia lyallii* Hook. f. and the average sizes of *O. lyallii* and *P. hookeri* are identical.

Since the pollen of *Olearia lyallii* and *Pleurophyllum* spp. are morphologically similar, and because many of the Compositae pollen grains on the peat slides were distorted it was decided to include the various genera under the family heading Compositae.

The occurrence of *Gaimardia* pollen, especially in the upper layers of profile 2, is noteworthy as this is the first record of Centrolepidaceae pollen in New Zealand peats (cf. Cranwell, 1953a).

In each profile there were a few pollen grains each of *Podocarpus dacrydioides* A. Rich., *Podocarpus* spp., *Dacrydium cupressinum* Soland., *Nothofagus menziesii* Oerst., and *Notofagus cliffortioides* Oerst. Erdtman (pers. comm.) did not detect such pollen in Auckland Islands material, but he did identify *Podocarpus* and *Dacrydium* pollen in Chatham Island samples (Erdtman, 1924).

At some horizons, the readily identifiable spores of the fern *Microsorium diversifolium* were abundant. There were too few smooth, monolete spores on any one slide to enable reliable identification. Fern genera identified included *Adiantum, Blechnum, Cyathea, Hymenophyllum,* and *Polystichum*. For diagrammatic purposes all fern spores, with the exception of *Microsorium diversifolium* have been counted together (Figs 8 and 9).

Long Distance Transport of Pollen

In each profile examined there are scattered records of gymnosperm and *Nothofagus* pollen. The number of samples in which these occurred are indicated in Figs 8 and 9. Pollen identified includes *Dacrydium cupressinum, Podocarpus dacrydioides, Phyllocladus, Nothofagus cliffortioides,* and *N. menziesii*. Neither gymnosperms nor *Nothofagus* grow on the Auckland Islands at present. The sporadic occurrence of these pollen in the peat profiles is consistent with the observed effects of long range wind dispersal of anemophilous pollen. Long range transport of pollen is not unknown in the southern hemisphere. Newman (1948) has trapped pollen and spores from an aeroplane above the Tasman Sea, Hafsten (1951) recorded *Nothofagus* pollen distributed through a peat profile from Tristan da Cunha and concluded that the southern coast of South America was their land of origin, the pollen having been air-borne for the great distance of nearly 3,000 miles. Erdtman (1924, 1943) reports that in Chatham Island peat, pollen grains of *Podocarpus* and *Dacrydium* formed about 1 to 5% of the total pollen. These genera do not occur on the Chatham Islands, which lie 400 miles east of New Zealand, and it is most likely that the pollen was carried from the main islands to the Chathams. There is therefore little reason to doubt that pollen has been wind carried from Stewart Island, or from the South Island of New Zealand, to the Auckland Islands.

The Auckland Islands lie about 200 miles S.S.W. of South Cape, Stewart Island. Meteorological observations (Table 1) for Port Ross available for the years 1941 to 1945 (Barnett, 1950), show that for the months September-December, which is the period of heaviest flowering, winds from the north, north-west, and north-east are frequent.

TABLE 1.—Meterological Data, Auckland Islands.

	Wind direction September-October No. days				Total for year		
	N.	N.W.	N.E.	Gales	N.	N.W.	N.E.
1941*	13½	35	9	6	39½	56½	22½
1942	6	22½	3	14	39½	92	19
1943	8	29	1	26	22½	92½	16
1944	12	27	6	7	30	84	15½
1945*	—	—	—	—	11	27	4

*Records not complete.

The islands are directly in line with the northerlies, and could be affected by the north-easterly winds. Of these, the north wind is the most important, which suggests that pollen could be carried from Stewart Island and the South Island.

The presence of these pollen grains, and the relative abundance of the podocarp pollens over the *Nothofagus* pollen is not without significance. *Podocarpus hallii* T. Kirk, *P. ferrugineus* D. Don, *P. spicatus* R. Br. and *P. dacrydioides* A. Rich. are all recorded for Stewart Island, and these, with the addition of *Podocarpus totara* D. Don., and *P. nivalis* Hook. all occur in the southern part of the South Island. Most species of *Dacrydium* are recorded from Stewart Island, including *Dacrydium cupressinum* Soland. which species is present in some of the peat samples. *Nothofagus* species are not found in Stewart Island, hence it is likely that these have been carried from the South Island.

There remains always the possibility of contamination from sources close to the laboratory. The samples were treated with as many precautions as were possible, and fresh supplies of glycerine jelly were used in mounting the slides. The persistence of the pollen throughout each profile is in itself sufficient to conclude that it has been derived from the peat sample and, in addition, many of the samples were prepared in the winter when the chances of pollen contamination are greatly reduced.

DISCUSSION

As the vegetation has developed on zonal peat the pollen diagrams (Figs 8 and 9) have been constructed from the total pollen counted,

with the exception of some herbaceous genera which were of sporadic occurrence only. Gymnosperm pollen and *Nothofagus* spp. pollen have also been excluded for reasons already discussed.

Pollen diagrams are amenable to a more satisfactory interpretation when other profiles from the same region have been examined. Execept for one profile from the Snares, none is available from this region, and thus interpretation is based mainly on the diagrams constructed for this paper.

Compositae pollen generally, represents herbaceous genera. *Olearia lyallii* is not an important element in the present Auckland Islands flora except on several small islands in Port Ross where it is abundant.

Metrosideros is important in each of the four profiles. The maximum in *Metrosideros* pollen is most marked in profiles 2 and 6. If these curves are accepted as reliable indicators, it is possible to divide the profiles into three stages, despite the fact that each profile is a truncated one.

The division of the Auckland Island pollen diagrams into three stages is based particularly on the evidence of the *Metrosideros* curves. The fact that *Metrosideros* may be found in all plant communities at the altitude of the peats investigated leads one to suspect that local factors have affected the pollen frequencies. *Metrosideros*, for example, is entomophilous, as are also *Suttonia divaricata* and *Dracophyllum longifolium*. But the great increase in frequency of *Metrosideros* in stage II, and the low frequency in stage III, does not suggest sporadic deposition of pollen.

The pollen record suggests the general succession of vegetation to be grassland and shrub → *Metrosideros* → grassland and shrub. The marked increase in *Metrosideros* pollen in stage II is a clear indication of great and rapid expansion of *Metrosideros* forest, and the abrupt decline in the pollen counts at the Stage II-III boundary illustrates a reversion to earlier conditions.

There are no comparable diagrams available from the New Zealand region, although Cranwell and von Post (1936) discussed the role of *Metrosideros* from Southland and Otago peat profiles. The Snares are only about 150 miles distant from and in the same climatic region as the Auckland Islands, and although *Metrosideros* is not represented in the Snares profile, the history of peat development on the two island groups could be expected to follow the same pattern.

Pollen diagrams from the Snares (Harris, 1953) show a decrease in tree pollen (*Olearia lyallii; Pleurophyllum* species are not recorded from the Snares) from the base of the profile upwards, an increase in grass pollen, and generally an increase in the other pollen. The base of the Snares profile correlates with the upper part of Stage II of the Auckland Island diagrams. Such a correlation implies that the Auckland Island peats have a longer history than the Snares peats and also, that the three stages represented in the Auckland Island diagrams are not

necessarily synchronous with the three post-glacial periods established for New Zealand by Cranwell and von Post (1936). Recent investigations in New Zealand (Raeside, 1948; Holloway, 1954; Harris, 1955) provide evidence of a warm, forest climate occurring between the 7th and 14th centuries A.D. Further, Harris (1953), concluded that the Snares peats are less than 2,500 years old, and added that in a personal communication, Holloway suggested that the peats might be no more than 1,000 years old. In the present state of knowledge, and in the absence of samples to which absolute dates can be assigned, it is suggested that the Auckland Island peats began accumulating in the earlier stages of the third post-glacial period and that stage II' of the diagrams described in this paper is correlated with the recent climate fluctuation already briefly discussed.

REFERENCES

ASTON, B. C., 1909: The Soils and Soil-formers of the Subantarctic Islands. "Subantarctic Islands of New Zealand". Vol. 2, Government Printer, Wellington, N.Z.

BARNETT, M. A. F., 1950: "Meteorological Observations for 1945". Government Printer, Wellington, N.Z.

CHILTON, C., 1909: "The Subantarctic Islands of New Zealand". Vol. I and II, Government Printer, Wellington, N.Z.

COCKAYNE, L., 1909: The Ecological Botany of the Subantarctic Islands of N.Z. "Subantarctic Islands of New Zealand". Vol. I, Government Printer, Wellington, N.Z.

————, 1928: "The Vegetation of New Zealand". Edition 2. Engelmann, Leipzig.

CRANWELL, L. M., 1953a: "New Zealand Pollen Studies: The Monocotyledons". *Auckland Inst. Bull 3.*

————, 1953b: An Outline of New Zealand Peat Deposits. *7th Pacif. Sci. Congr. 5* : 1-23.

CRANWELL, L. M.; VON POST, L., 1936: Post-pleistocene pollen diagrams from the Southern Hemisphere I. New Zealand. *Georgr. Ann. Stockh, 3-4* : 308-47.

ERDTMAN, G., 1924: Studies in micro-palaeontology. IV. Peat from the Chatham Islands and Otago District. *Geol. Foren. Stockh. Forh. 46 (6-7)* : 679-81.

————, 1943: "An Introduction to Pollen Analysis". Chronica Botanica, Waltham, Mass.

FALLA, R. A., 1948: The Outlying Islands of New Zealand. *N.Z. Geogr. 4 (2)* : 127-54.

HAFSTEN, ULF, 1951: "A Pollen-analytical investigation of two peat deposits from Tristan da Cunha". Results of Norweg. Exped. T. da Cunha, 1937-1938, No. 22.

HARRIS, W. F., 1953: The Geology of the Snares Islands Part III: Peat Samples. *N.Z. Cape Exped. Ser. Bull 13.*

————, 1955: Progress report on pollen statistics from Pyramid Valley Swamp. *Rec. Canterbury [N.Z.] Mus. VI (4)* : 279-90.

HOLLOWAY, J. T., 1954: Forests and Climates in the South Island of New Zealand. *Trans. roy. Soc. N.Z. 82 (2)* : 329-410.

NEWMAN, I. V., 1948: Aerobiology on Commercial Air Routes. *Nature, Lond. 161* : 275.

OLIVER, R. L.; SORENSEN, J. H., 1951: Botanical Investigations on Campbell Island. Part I. *N.Z. Cape Exped. Ser. Bull. 7.*

RAESIDE, J., 1948: Some post-glacial climate changes in Canterbury and their effect on soil formation. *Trans. roy. Soc. N.Z. 77 (1)* : 153-71.

TAYLOR, B. W., 1955: The Flora, Vegetation, and Soils of Macquarie Island. Austr. Nat. Antarct. Res. Exped. Rep., *Series B. Vol. 2. Botany.*

NOTES ON THE BOTANY OF THE AUCKLAND ISLANDS

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Summary

Brief notes on the vegetation and the flora of the Auckland Islands are presented in order to supplement the recorded observations of earlier workers.

Introduction

The author visited the Auckland Islands (Moar, 1958, Fig. 1) which lie between 50° 26′ and 50° 56′ S, and 165° 52′ and 166° 22′ E, about 200 miles S.S.W. of the south coast of the South Island, New Zealand, from 4 to 13 November 1954, as a member of an expedition sponsored by the Department of Scientific and Industrial Research and led by Dr R. A. Falla, Director, Dominion Museum.

The study of peat vegetation (Moar, 1958) and the collection of samples for pollen analysis occupied most of the available time, but as this work proceeded, some general observations were made, and are recorded in this paper. Particular attention was given to the collection of plant specimens, both for inclusion in the Botany Division herbarium and for cultivation at the experimental gardens of the Botany Division, D.S.I.R., most of this work being undertaken by Dr J. B. Hair, Senior Cytologist, Botany Division.

Areas close to Ranui Cove were explored, Ewing Island, Ocean Island, and French Islet in Port Ross were visited, and a brief visit was made to Adams Island in the south. Because no area was examined in detail, this paper purports to be no more than supplementary to the careful descriptions of the vegetation already published (Cockayne, 1904, 1909, 1928).

Vegetation

Metrosideros forest

Forest dominated by *Metrosideros umbellata* grows at low levels over much of Auckland Island, and has been described by Cockayne (1909, 1928). On Ewing Island and on Ocean Island, however, there are small unrecorded areas of *Metrosideros* forest.

In the centre of Ewing Island there is a vigorous community of *Metrosideros* and *Olearia lyallii* surrounded by dense *Olearia lyallii* forest. The wet peat surface under these trees is bare except for scattered colonies of *Asplenium obtusatum*, *Blechnum durum*, and

Polystichum vestitum. Cockayne (1904) described *Metrosideros* forest on Ewing Island, but did not refer to *Metrosideros* growing within *Olearia* forest. Falla (1948) referred to this unusual community and suggested that the *Olearia lyallii* may have grown on a man-made clearing. Dr Falla (pers. comm.) has given as his reason for this suggestion the following facts regarding this and two other areas of *Olearia* thicket noted by Cockayne and other observers.

(a) A small patch at the head of Laurie Harbour is on a site described by Ross (1847) as a clearing for huts of French whalers.

(b) A big patch on the peninsula at Erebus Cove is shown by contemporary sketches to have been completely cleared before 1870.

(c) Though no early pictures or exact records of transactions at Ewing Island are extant it seems certain that the shore equipment and boats of the short-lived whaling venture (1850-52) were beached on the conveniently low shore slopes of the island, which presumably were kept cleared.

On Ocean Island the vegetation is slowly recovering from the depredations of goats only recently exterminated. An open community dominated by *Metrosideros umbellata*, 20 ft high, occurs in the centre of the island. Here many *Metrosideros* trees are dead. Other species present include:

Dracophyllum longifolium
Suttonia divaricata
Hebe elliptica
Stilbocarpa polaris
Stellaria decipiens
Poa foliosa
Carex trifida
Scirpus aucklandicus
Histiopteris incisa
Asplenium lucidum

A narrow zone of *Dracophyllum longifolium* and *Hebe elliptica*, in which there are many dead *Metrosideros* trees, surrounds the central forest area. *Dracophyllum* is heavily infested with a sooty fungus. This is the only locality where a heavy infestation was seen. Cockayne (1909) noted that infestations of a sooty fungus *Antennaria scoriadea* Berk. were frequent on *D. longifolium*.

Bogs and Swamps

The vegetation of bogs examined in the vicinity of Ranui Cove is described elsewhere (Moar, 1958). Cockayne (1909) referred to swamps, sometimes at sea-level, in which grow *Stilbocarpa polaris* and *Pleurophyllum criniferum*. No such plants were seen in the few wet

places noted by the author; neither were they found along swampy stream banks, except on Adams Island. A small swamp on a narrow, rocky, wave-cut platform at the northern end of Ocean Island was examined. In this swamp there are clumps of *Carex trifida,* and on drier areas, *Poa litorosa* is common. In moist places amongst the rocks are *Rumex neglectus, Tillaea moschata, Montia fontana,* and *Poa annua*.*

FLORA

Phenology

The following notes extend, or record for the first time, the flowering times of some of the species of the Lord Auckland Group. The notes are arranged as follows:

(1) The author's observations (4 to 13 November 1954).

(2) Flowering times recorded in Cheeseman (1925).

(3) Notes by Cockayne (1904, June; 1909, November).

(4) Observations by other authors.

Omission of a number implies that there is no record.

Ranunculus acaulis

(1) Specimens from Ewing Island, in Port Ross were in full flower. No fruiting specimens were seen.

(2) Flowering between September and November.

Ranunculus aucklandicus

(1) Specimens from Ewing Island were in full flower; early stages of fruit formation were also noted.

(3) Numerous blooms on Adams Island (November).

Cardamine sp.

(1) On Ewing Island, Ocean Island, and Adams Island the plant was in full flower. There were immature fruits on many plants.

Stellaria decipiens

(1) This species, found on the coast at all areas investigated, was in full flower. No fruits were observed.

Tillaea moschata

(1) Some plants bore a few flowers. No fruit was seen.

*Denotes an adventive species.

Callitriche antarctica

(1) (a) A large-leaved form occurring in wetter parts of the forest was in early stages of flowering.
(b) A small-leaved form in open forest, and in wetter coastal areas, was in full flower.

Metrosideros umbellata

(1) All specimens examined bore flower buds.
(2) November-January.
(3) "*Metrosideros lucida* during January will turn the forest into a blaze of crimson." The species may bear flowers as late as March (1904).

Anisotome latifolia

(1) Two plants bearing flower buds were found on Adams Island.
(2) November-January.
(3) Occasional blooms recorded. This record presumably refers to plants on Adams Island (1909).

Stilbocarpa polaris

(1) In full flower on French Islet, Ewing, Ocean, and Adams Islands. A few of last season's fruits were collected on Ewing Island.
(2) December-January.
(3) Occasional blooms on Adams Island. Cockayne (1909) recorded that plates in *Voyage au Pole Sud* illustrate flowering specimens of this plant collected during March.
(4) Chapman (1891) stated that this species was in flower on 5 January, 1890.

Coprosma foetidissima

(1) Ripe fruits were seen on some shrubs.
(2) August-October.

Nertera depressa

(1) No flowers seen. Some plants bore ripe fruits.
(2) October-January.

Pleurophyllum speciosum

(1) Seen only on Adams Island, this species was in the vegetative state.
(2) December-January.
(3) Flowers profusely in December (1904, 1909).

Pleurophyllum criniferum

(1) As for *P. speciosum.*
(2) December-January.
(3) Flowering on Adams Island in November (1900).

Celmisia vernicosa

(1) Seen on Adams Island. Here there were only a few plants in flower.
(2) November-December.
(3) Numerous blooms on Adams Island in November (1909).

Helichrysum bellidioides

(1) Found on Ocean Island, specimens were in early flowering stages.

Cotula plumosa

(1) Common on coastal cliffs of Auckland Island, Ewing Island, and Adams Island. Some specimens were in full flower, others were in bud, and many were in the vegetative state.
(2) December-January.
(3) Occasional flowers noted (1909).

Cotula lanata

(1) On coastal cliffs and rocks on French Islet, Ewing Island, and Adams Island. Many plants were in full flower.
(2) December-January.
(3) Occasional flowers seen (1909).

Phyllachne clavigera

(1) On covex bogs in Port Ross, and also seen on Adams Island. This species was in full flower.
(2) December-March.
(3) Cockayne records numerous blooms in the middle of November (1909).

Dracophyllum longifolium

(1) Common in *Metrosideros* forest, in scrub, and in tussock areas. This species was in early stages of flowering. Some individual plants were in full flower.
(2) November-March.
(3) Cockayne (1909) stated that plates in *Voyage au Pole Sud* show that specimens collected at the beginning of March were in flower.

Gentiana concinna

(1) Observed on raised bogs and in *Metrosideros* forest at Port Ross. Only two plants were in flower, and when petals of one flower were separated fruit was found. The anthers were shrivelled and pollen had been shed.

Myosotis capitata

(1) Seen only on Adams Island this plant was approaching full flower. Plants generally, bore a mass of flower buds.
(2) December-January.
(3) Numerous blooms in November (1909).

Hebe benthami

(1) Seen only on Adams Island where the flowering period was almost finished. There were young capsules on most specimens collected.
(2) December-February.
(3) Numerous blooms in November (1909).

Plantago brownii

(1) On the coast at French Islet, Ewing Island, and Ocean Island. Young flower buds were hidden by leaves.

Astelia linearis var. *lincaris*

(1) On raised bogs at Port Ross. Fruiting plants were occasionally seen.
(3) Occasional blooms in November (1909).

Astelia subulata

(1) Occurring in the same areas as *Astelia lincaris* var. *lincaris*, this species was in the late flowering stage. Young fruits were common.
(3) Occasional blooms (1909).

Bulbinella rossii

(1) Adams Island was the only locality* where numbers of this plant were seen by the writer. There were only a few plants in flower (Fig. 1). One plant was found at Ranui Cove in Port Ross.

**Bulbinella rossii* is abundant on Enderby Island and Rose Island.

FIG. 1.—*Bulbinella rossii* in flower on Adams Island. Other species present include *Pleurophyllum criniferum* (mid left), *Pleurophyllum speciosum* (foreground), *Anisotome latifolia* (right foreground).

(2) December-January.
(3) Cockayne (1909) noted occasional blooms in January, and added that plates in *Voyage au Pole Sud* show that flowers may be found as late as March.
(4) Chapman (1891) noted fruit on January 5, 1890.

Carex trifida

(1) This species was in full flower on French Islet, Ewing, Ocean, and Adams Islands.

Notes on Some Species

Despite the fact that the flora of the Auckland Islands is well known, there is likely to be some new data available after any expedition, no matter how brief. In this section information is recorded on indigenous species and adventive species which so far has not been reported in the literature.

Indigenous Species

Rumex neglectus

This plant, which occurs in scattered localities around the coast-line of New Zealand from Wellington south, has colonized considerable areas of disturbed sand-dunes on Enderby Island (Cockayne, 1904, 1909, 1928). It also occurs on gravelly beaches on northern parts of the Island group (Hooker, 1847; Cheeseman, 1909, 1925) and there are extensive colonies growing in small swamps close to sea-level on Ocean Island, in association with *Carex trifida, Tillaea moschata, Montia fontana,* and *Poa annua**. There is no record in the literature of *Rumex neglectus* growing under such conditions on the Auckland Islands.

Callitriche antarctica

Two forms of this species were found in Ranui Cove. One form with a coarse, open habit was confined to the wetter parts of the forest. The other, smaller and finer in habit, grew in compact mats in open areas in the forest and at the coast. Hooker (1847) noted the two forms, and Taylor (1955) referred to two forms—one terrestrial, and one aquatic—on Macquarie Island. He concluded that these two forms are merely an expression of different habitat conditions. It is worth noting that when the two forms were grown under identical conditions in the Botany Division experimental gardens, now in the village of Lincoln, the differences tended to disappear (Miss R. Mason, pers. comm).

There is no morphological difference between the pollen of the two forms. On the other hand, pollen of *Callitriche antarctica* from the Auckland Islands and from Campbell Island show differences in size, pore shape, and exine characters. The identity of these plants is still being investigated by Miss R. Mason of Botany Division, and their pollen characters are being studied by the writer.

Metrosideros umbellata

On Ocean Island there were many dead *Metrosideros* trees killed by the once dense goat population (Wodzicki, 1950). With the extermination of the goats some time after 1943, the vegetation has been regenerating, and there is now no evidence of a continuing high mortality in *Metrosideros*.

There were dead trees in the vicinity of Ranui Cove, but here mortality was not so high as to suspect other than natural causes. There were no clumps in which all the trees were dead, and there was no obvious sign of insect infestation on the trees. Some trees, which from a distance appeared to be dead, were found, on closer inspection, to be bearing short leafy twigs on the bole and at the bases of dead branches.

There were dead *Metrosideros* shrubs on the raised bogs. Death of these has been related to cycles of growth and decay usual in such bogs and is discussed elsewhere (Moar, 1958).

FIG. 2.—*Stilbocarpa polaris* at margin of *Olearia lyallii* forest on Ewing Island.

Stilbocarpa polaris

References in earlier papers (Hooker, 1847; Kirk, 1891; Cockayne, 1904, 1909, 1928) indicate that this species was once common throughout the Auckland Group. Hooker (1847) stated that it was found growing "on rocks and banks near the sea, or amongst the dense and gloomy vegetation of the woods. . . ." With the exception of a few depauperated specimens on Ocean Island growing in an open *Metrosideros* community, none was seen associated with *Metrosideros* forest. Indeed, of the areas visited, *Stilbocarpa polaris* was growing vigorously only at the margin of *Olearia* forest on Ewing Island (Fig. 2), on French Islet, and on the lower slopes of Adams Island. On Auckland Island the author heard goats, and saw a number of pigs, and in non-forested areas pig rootings were common. There is no doubt that goats and pigs have reduced the numbers of this species, and as long ago as 1847 Hooker stated that *Stilbocarpa polaris* was "greedily eaten by goats, pigs, and rabbits." There are no goats or pigs on Ewing Island or French Islet, and since about 1943 there have been none on Ocean Island.

Anisotome antipoda and *Anisotome latifolia*

These species were apparently much more abundant formerly than they are now, and of the two species *A. latifolia* was the only one collected outside Adams Island. It was found in relatively inaccessible localities no doubt having been eaten out of other areas by grazing animals.

Coprosma cuneata

Bud galls on *Coprosma cuneata* were submitted to Dr K. P. Lamb, Plant Diseases Division, D.S.I.R., for identification who comments as follows: "These pilose bud galls are not uncommon on *Coprosma* spp., and are caused by the Eriophid mite *Aceria cottieri* Lamb, 1952 (Trans. roy. Soc. N.Z. 79 : 358). Mites from the *C. cuneata* galls were morphologically indistinguishable from type material originally collected from *Coprosma robusta* galls in Auckland, New Zealand."

ADVENTIVE SPECIES

Fragaria sp.

One strawberry plant was growing near the huts erected in 1940 for Coast Watchers at the head of Ranui Cove. This is now growing in the Botany Division experimental gardens, but accurate identification to species is not yet possible (Mr A. J. Healy, pers. comm.).

It is known that Sir Joseph Hooker distributed gooseberry, currant, raspberry, and strawberry plants over parts of Auckland Island in November 1840, but it is unlikely that the plant found has descended from one of these strawberry plants. From its close proximity to the huts it was doubtless introduced in some way by the coast-watching personnel resident there during the Second World War.

This is the first record of *Fragaria* being found on the Auckland Islands in the adventive state.

Myosotis sp.

Vegetative specimens of a large-leaved *Myosotis* were collected at the camp in Ranui Cove. These do not compare with specimens of indigenous species of *Myosotis,* and in the vegetative state cannot be identified with species adventive to New Zealand. Although identification to the species level cannot be made, the occurrence of an adventive *Myosotis* on the Auckland Islands is a new record.

Phormium tenax

On the southern bank of Ranui Cove there is a community of *Phormium tenax* said to be introduced by Maoris at about the time of the Enderby settlement in 1849 (Cockayne, 1904). There is no evidence to suggest that the species is spreading, and Dr Falla (pers. comm.) who has visited the Auckland Islands on several occasions, is of the

opinion that the community has not increased in size in recent years. He reports (pers. comm.) that other restricted patches are to be found behind accessible beaches farther down the east coast.

Catalogue of Plants

The following is a list of the plants collected from the Auckland Islands. They are either preserved in the Botany Division herbarium, or are growing in the Botany Division experimental gardens. The fact that the localities at which each species was collected is listed does not imply that the species are restricted to those localities.

Lycopodiaceae

Lycopodium varium R.Br. Auckland Isd.

Schizaeaceae

Schizaea fistulosa Labill. var. *australis* (Gaud.) Hook.f. Auckland Isd.

Hymenophyllaceae

Hymenophyllum multifidum (Forst.f.) Schroeder. Auckland Isd.

Dennstaedtiaceae

Blechnum durum (Moore) C. Christen. Ocean Isd.
Polystichum vestitum (Sw.) Presl. Ocean Isd.

Ranunculaceae

Ranunculus acaulis Banks et Sol. Ewing Isd., Ocean Isd., French Islet, Adams Isd.
Ranunculus aucklandicus A. Gray. Ewing Isd.

Cruciferae

Cardamine corymbosa Hook.f. Ocean Isd.
Cardamine depressa Hook.f. Ewing Isd.

Crassulaceae

Tillaca moschata DC. Ocean Isd., French Islet, Adams Isd.

Caryophyllaceae

**Cerastium glomeratum* Thuill. Auckland Isd., Ocean Isd.
Colobanthus muscoides Hook.f. Ocean Isd., Ewing Isd., French Islet.
Colobanthus sp. Auckland Isd., Ocean Isd., French Islet.
Stellaria decipiens Hook.f. Auckland Isd., Ewing Isd., French Islet.
**Stellaria media* (L.)Vill. Auckland Isd.

Portulacaceae

Montia fontana L. Ocean Isd

Polygonaceae

**Rumex acetosella* L. Auckland Isd.
Rumex neglectus T. Kirk. Ewing Isd., French Islet.

Geraniaceae

Geranium microphyllum Hook.f. Adams Isd.

Onagraceae

Epilobium confertifolium Hook.f.
Epilobium linnaeoides Hook.f. Auckland Isd.

CALLITRICHACEAE

Callitriche antarctica Engelm. Auckland Isd.

MYRTACEAE

Metrosideros umbellata Cav. Auckland Isd.

ROSACEAE

Acaena sp. Ocean Isd., French Islet, Auckland Isd.
**Fragaria* sp. Auckland Isd.

URTICACEAE

Urtica australis Hook.f. Ewing Isd., French Islet.

ARALIACEAE

Nothopanax simplex Seem. Auckland Isd.
Stilbocarpa polaris A. Gray. Ocean Isd., Ewing Isd., Adams Isd., French Islet.

UMBELLIFERAE

Anisotome antipoda Hook.f. Adams Isd.
Anisotome latifolia Hook.f. Adams Isd., French Islet.
Lilaeopsis sp. Ewing Isd.

EPACRIDACEAE

Dracophyllum longifolium (Forst.) R.Br. Auckland Isd.
Dracophyllum sp. Auckland Isd.
Cyathodes empetrifolia Hook.f. Auckland Isd.

MYRSINACEAE

Suttonia divaricata Hook.f. Auckland Isd.

RUBIACEAE

Coprosma cuneata Hook.f. Auckland Isd.
Coprosma foetidissima Forst. Auckland Isd.
Coprosma pumila Hook.f. Auckland Isd., Adams Isd.
Nertera depressa Banks et Sol. Auckland Isd., Adams Isd.

COMPOSITAE

**Achillea millefolium* L. Auckland Isd.
Cassinia vauvilliersii Hook.f. Auckland Isd.
Celmisia vernicosa Hook.f. Adams Isd.
Cotula lanata Hook.f. Ewing Isd., Ocean Isd., Adams Isd., French Islet.
Cotula plumosa Hook.f. Ewing Isd.
Helichrysum bellidioides Willd. Ocean Isd.
Lagenophora pumila Cheesem. Auckland Isd.
Olearia lyallii Hook.f. Ewing Isd.
Pleurophyllum criniferum Adams Isd.
Pleurophyllum speciosum Adams Isd.
Sonchus oleraceus L. Auckland Isd.

GENTIANACEAE

Gentiana concinna Hook.f. Auckland Isd.

PRIMULACEAE

Samolus repens Pers. Ewing Isd.

PLANTAGINACEAE

Plantago brownii Rap. Ewing Isd., Adams Isd., French Islet.

STYLIDIACEAE

Phyllachne clavigera F. Muell. Auckland Isd.

BORAGINACEAE

Myosotis capitata Hook.f. Adams Isd.
**Myosotis* sp. Auckland Isd.

SCROPHULARIACEAE

Hebe benthami Hook.f. Adams Isd.
Hebe buxifolia (Benth.) Ckn. et Allan. Auckland Isd.
Hebe sp. Auckland Isd.

LILIACEAE

Astelia linearis Hook.f. var. *linearis* Auckland Isd.
Astelia subulata (Hook.f.) Cheesem. Auckland Isd.
Bulbinella rossi Benth. et Hook.f. Adams Isd.

ORCHIDACEAE

Corybas oblongus (Hook.f.) Reichb.f. Auckland Isd.
Chiloglottis cornuta Hook.f. Auckland Isd.

CENTROLEPIDACEAE

Gaimardia ciliata Hook.f. Auckland Isd., Ewing Isd.

CYPERACEAE

Carex trifida Cav. Ocean Isd.
Oreobolus pectinatus Hook.f. Auckland Isd., Adams Isd.
Scirpus aucklandicus (Hook.f.) Boeck. Auckland Isd.
Scirpus cernuus Vahl. Auckland Isd.
Scirpus sp. Ewing Isd.
Uncinia riparia R.Br. var. *hookeri* (Boott) Kukenth. Auckland Isd.

GRAMINEAE

**Poa annua* L. Auckland Isd., Ocean Isd.
Poa foliosa Hook.f. Ocean Isd.
Poa ramosissima Hook.f. Auckland Isd.
Poa litorosa Cheeseman. Ocean Isd.

REFERENCES

CHAPMAN, F. R., 1891: The Outlying Islands south of New Zealand. *Trans. N.Z. Inst. 23* : 491-522.

CHEESMAN, T. F., 1909: On the Systematic Botany of the Islands of the South of New Zealand. "Subantarctic Islands of New Zealand". Vol. 2. Government Printer, Wellington, New Zealand.

————, 1925: "Manual of the New Zealand Flora". Government Printer, Wellington, New Zealand.

COCKAYNE, L., 1904: A Botanical Excursion during Midwinter to the Southern Islands of New Zealand. *Trans. N.Z. Inst. 36* : 225-333.

————, 1909: The Ecological Botany of the Subantarctic Islands of New Zealand. "Subantarctic Islands of New Zealand." Vol. I, Government Printer, Wellington, New Zealand.

————, 1928: "The Vegetation of New Zealand". Edit. 2. Engelmann, Leipzig.

FALLA, R. A., 1948: The Outlying Islands of New Zealand. *N.Z. Geogr. 4 (2)* : 127-54.

HOOKER, J. D., 1847: "Flora Antarctica". Vol. 1. Reeve, London.

KIRK, T., 1891: Report on a Botanical Visit to Lord Auckland, Campbell, Antipodes, and other Antarctic Islands. *J. Linn. Soc. (Bot.) 28 (194)* : 327.

MOAR, N. T., 1958: Contributions to the Quaternary History of the New Zealand Flora. I. Auckland Island Peat Studies. *N.Z. J. Sci. 1* : 449-65.

TAYLOR, B. W., 1955: The Flora, Vegetation, and Soils of Macquarie Island. *Austr. Nat. Antarct. Res. Exped. Rep. Ser. B,* Vol. 2. Botany.

WODZICKI, K. A., 1950: "Introduced Mammals of New Zealand." *N.Z. Dept. sci. industr. Res. Bull. 98.*

CONTRIBUTIONS TO THE QUATERNARY HISTORY OF THE NEW ZEALAND FLORA

2. PLANT REMAINS FROM A BURIED PEAT LAYER AT BOWENVALE, CHRISTCHURCH

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(Received for publication, 11 June 1958)

Summary

Plant fragments from a peat layer three feet thick and buried by five feet of silt are listed and are briefly discussed. Wood from the base of the profile has been assigned an age of 940 ± 70 years by the ^{14}C method.

Introduction

In April 1956, Mr B. W. Collins, Geological Survey, Christchurch, drew the author's attention to a peat layer in an excavation made for bridge piles on the southern side of the Heathcote River near the mouth of the Bowenvale Valley, one of the many short, narrow valleys typical of the Port Hills, Christchurch (Fig. 1).

The peat layer, which was three feet thick, was buried under five feet of silt and underlain by a bright-blue clay. Rootlets and wood remains could be seen in the exposed peat, and large pieces of wood excavated from the profile were scattered around the edge of the hole. In the middle of the peat layer was a mass of *Phormium* leaf bases, and at various levels were rootlets of *Carex secta* Boot. After a careful examination it was obvious that the peat and the underlying clay contained plant remains so numerous that a detailed investigation was warranted.

A wood sample from the base of the peat layer was collected by Mr Collins for dating by the ^{14}C method.

The peat contained so much sand and silt that available laboratory facilities made the preparation of slides for pollen analysis impracticable. Samples collected for this purpose are stored for later examination.

Eleven samples*, including one from the underlying clay, were taken for the extraction of plant remains. Samples were digested in 50% nitric acid and then washed through a sieve with thirty meshes per inch (B.S. No. 410/1943). Specimens were stored in glycerol-formalin.

This paper presents details of plant material identified, as a contribution to the knowledge of the Quaternary flora of New Zealand.

*Samples are at 10cm intervals and are numbered in sequence from the top of the peat layer.

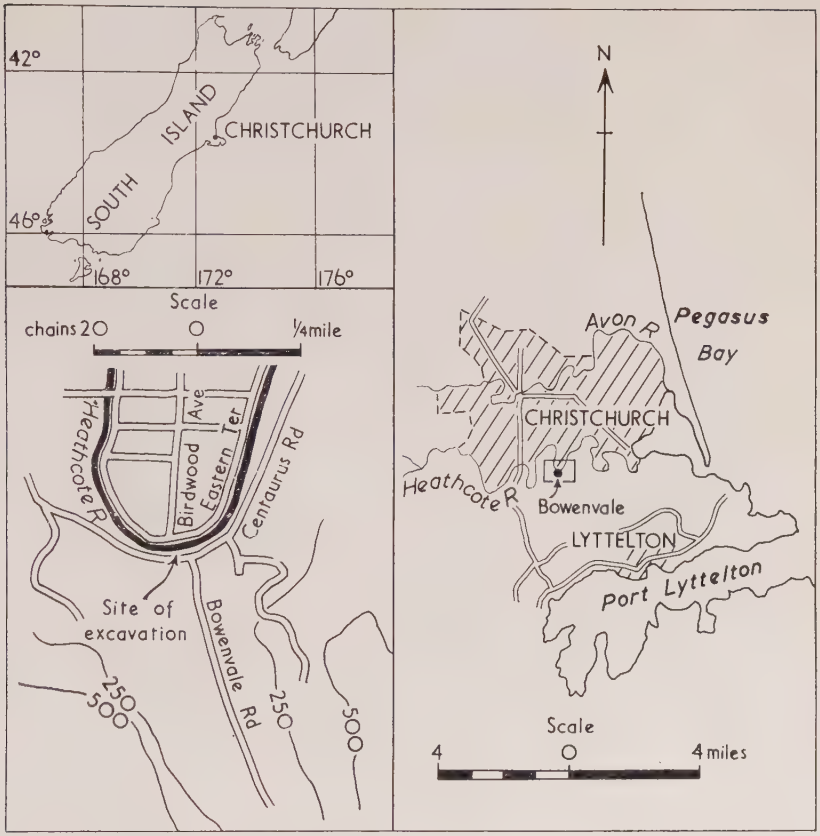

FIG. 1.—Map of Christchurch and Port Hills, and location of the excavation from which the profile was obtained.

RESULTS

PODOCARPACEAE

Podocarpus spicatus R.Br.

Several seeds of *Podocarpus spicatus* were detected in samples 8 and 9 (Fig. 3).

Podocarpus dacrydioides A. Rich.

(a) Leaves of *Podocarpus dacrydioides* were identified from samples 5, 6, 7, and 11. In the first three samples leaves were numerous and twigs with leaves attached were also present. Similar remains have been recorded from Paekakariki peats (Moar, 1954).

(b) Immature male cones no more than 3mm long were found in samples 6 and 8. These compared well with immature cones on herbarium specimens of *Podocarpus dacrydioides*. Small, obviously immature pollen was crushed from unopened pollen sacs. Many of the pollen grains were clumped together, and all of them were quite unaffected by basic fuchsin stain (Fig. 2).

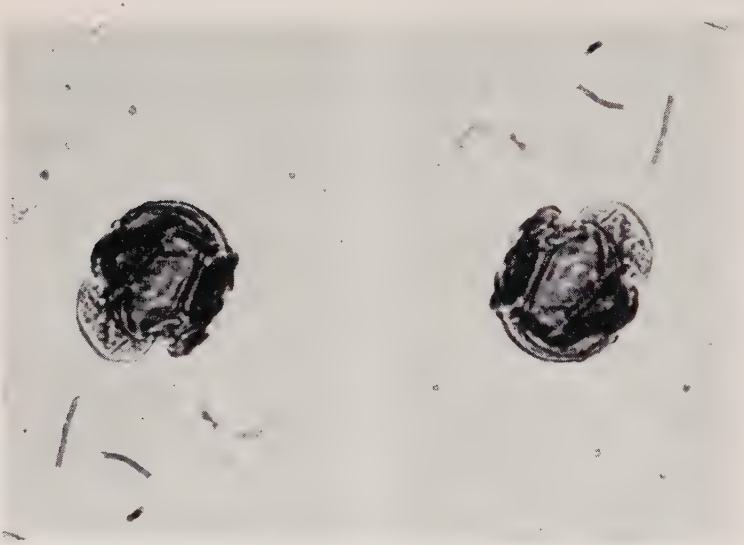

FIG. 2.—Immature pollen of *Podocarpus dacrydioides*.
Photo: R. A. Couper.

An old cone, from which all the pollen had been shed, was recovered from sample 8.

Podocarpus sp.

(a) In samples 6, 7, 8, 9, and 11 there were many leaves of *Podocarpus* sp. The leaves resembled those of *Podocarpus totara* D. Don, but as there is a close similarity between the leaves of *P. totara* and *Podocarpus hallii* T. Kirk no specific identification was attempted.

(b) Pollen from a cone found in sample 8 was placed in the *Podocarpus totara-hallii* group.

WINTERACEAE

Drimys colorata Raoul

(a) Samples 8 and 9 yielded seeds of *Drimys colorata* (Fig. 3). They were slightly smaller than seeds in the Botany Division herbarium, which,

however, show a considerable variation in size. The sub-fossil seeds were more corrugated than herbarium specimens, but after soaking in 10% KOH, the corrugations in recent seeds became more pronounced.

(b) A pedicel was extracted from sample 8. Comparison with herbarium material confirms its identity.

(c) Leaf fragments were identified in sample 8. One leaf was almost whole, with only the petiole and a small portion of the base missing. Venation is reticulate, the main veins forming a series of loops which enclose a reticulum of minor veins. Near the apex the loops are small and indistinct. On the best preserved surface there are small circular markings comparable with the "pellucid dots" described by Cheeseman (1925). The apex of the leaf is rounded and slightly retuse. These features agree well with those of leaves of *Drimys colorata* taken from authenticated specimens in the Botany Division herbarium and cleared in 5% KOH.

HALORAGACEAE

Haloragis erecta Schindler

Samples 3, 4, 5, and 6 yielded several fruits. The calyx and the corolla of each had been lost, and the wings, so characteristic of *Haloragis erecta* had been destroyed, so that the specific identity was not at first apparent. The pattern of the rugae and the strongly four-angled shape, however, precludes the possibility of the fruit being identified with other *Haloragis* species.

CORIARIACEAE

Coriaria arborea Lindsay

Seed from samples 6, 7, 8, and 11 were identified on the basis of ridge number and their disposition, size, and shape.

MYRTACEAE

Myrtus obcordata Hook.f.

Several seeds were found in sample 8 (Fig. 3).

Leptospermum ericoides A. Rich.

There were six poorly preserved capsules in samples 7 and 8.

ROSACEAE

Rubus australis Forst.f.

Two fruits were identified in sample 7.

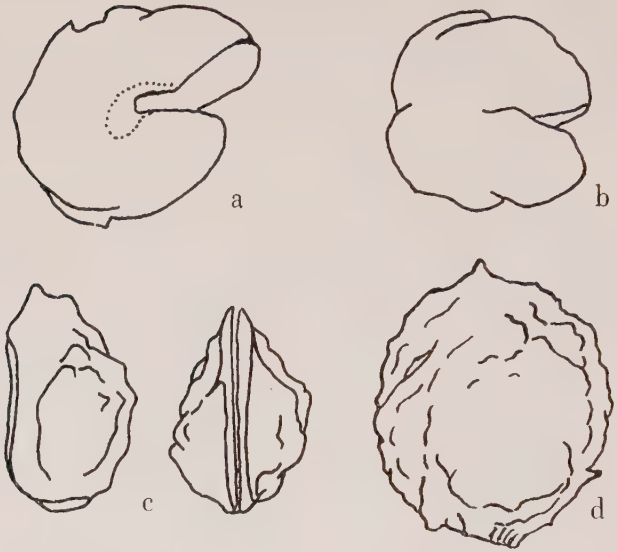

FIG. 3.—Seeds: (a) *Myrtus obcordata* × 10
(b) *Myrtus obcordata* × 10
(c) *Drimys colorata* × 10
(d) *Podocarpus spicatus* × 5

FAGACEAE

Nothofagus sp.

Leaf fragments were recovered from samples 8 and 9. Comparison with herbarium material permits identification to generic level, but as the material was fragmentary no attempt was made to place the specimens in either *Nothofagus solandri* or *N. cliffortioides*, which species they resemble.

ARALIACEAE

Nothopanax arboreum Seem.

Single cells of the two celled fruit of *Nothopanax arboreum* were identified in samples 6, 7, and 8.

COMPOSITAE

Liguliflorae?

One compressed achene without pappus hairs was found in sample 5. Conspicuous, faintly serrated ribs, and the basal arrangement of the ribs may be compared with similar features on achenes of the Liguliflorae.

CYPERACEAE

Sedge remains were common in the peat and in the underlying clay.
Carex secta Boott

(a) Many utricles were identified. The outer layers have been destroyed, including the "wings" at the shoulder of the utricle. The shape, especially the rounded base and the plano-convex outline, compares well with utricles of *Carex secta*. Several utricles were broken open to reveal nuts comparable with those of *C. secta*.

(b) There were many nuts separated from, and a number only partly enclosed by, disintegrating utricles.

(c) Clumps of roots typical of the "trunk" of *Carex secta* were located at various levels in the profile.

Carex spp.

Nuts of two types were numerous. In one, the nuts are trigonous and could not be identified below the generic level. In the other, the nuts are plano-convex and ovate or elliptic-ovate in outline. These are similar to nuts of *Carex ternaria* Forst., but as many of them are split and broken exact identification was not attempted.

DISCUSSION

Species listed in this paper are found on the Port Hills of Christchurch today, albeit in greatly reduced numbers. The presence of remains of *Carex secta, Phormium* sp., *Podocarpus dacrydioides* and *P. spicatus* suggest a swampy area subject to flooding from the Heathcote River and from the Bowenvale Valley. Similar areas are now found in remnants of swamp or semi-swamp forest on Banks Peninsula and in Christchurch. Remains of *Drimys colorata, Nothopanax arboreum,* and *Podocarpus* sp. could easily have been washed into the accumulating peat from nearby slopes of the Port Hills.

The sample (D.N.S. Lab. No. R91/2, N.Z. Fossil No. S84/521-009521) has been assigned an age of 940 ± 70 years, by the Division of Nuclear Sciences, D.S.I.R. Thus, most of the peat is less than 1000 years old. Raeside (1948), Holloway (1954), and Harris (1955) have suggested that a change to a cooler climate occurred at about the 14th century A.D., and although no definite conclusions can be drawn from this one profile, it would appear that peat accumulation had begun before the postulated climate change and ceased at about the time of the transition to a cooler climate.

The results obtained from this profile have proved so interesting that samples from other localities within the Christchurch area have been obtained and work on these is proceeding.

Acknowledgements

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References

Cheeseman, T. F., 1925: "Manual of the New Zealand Flora". Edition 2. Government Printer, Wellington, New Zealand.

Harris, W. F., 1955: Progress Report on Pollen Statistics from Pyramid Valley swamp. *Rec. Canterbury [N.Z.] Mus. 6 (4)* : 279-90.

Holloway, J. T., 1954: Forests and Climates in the South Island, New Zealand. *Trans. roy. Soc. N.Z. 82 (2)* : 329-410.

Moar, N. T., 1954: Peat Profiles, Whareroa Block, Paekakariki, New Zealand. *N.Z. J. Sci. Tech. 36A (3)* : 221-31.

Raeside, J. D., 1948: Some Post-glacial Climatic changes in Canterbury and their effect on Soil Formation. *Trans. roy. Soc. N.Z. 77 (1)* : 153-71.

NEW ZEALAND
JOURNAL OF GEOLOGY AND GEOPHYSICS
Volume 1, No. 3, August 1958

CONTENTS

Quaternary Andesitic Volcanism at the Solander Islands. *H. J. Harrington* and *B. L. Wood* 419
Uranium Mineralization in the Hawks Crag Breccia of the Lower Buller Gorge Region, South Island, New Zealand. *A. C. Beck, J. J. Reed,* and *R. W. Willett* 432
A Note on the Formation of Native Iron and other Effects Associated with Contact of Basalt and Carbonized Wood at Auckland, New Zealand. *E. J. Searle* 451
Reports of a Submarine Eruption off New Zealand in 1877. *D. R. Gregg* 459
Submarine Geology of Bluff Harbour. *B. L. Wood* 461
Evidence of a Late Pliocene Warmth in New Zealand. *C. A. Cotton* 470
Distribution of Populations of Fossil Foraminifera. *G. H. Scott* 474
Geology of Motuihe Island, Waitemata Harbour. *C. J. Schofield* 485
The Structural Position of the Opau Greywackes, Hawke's Bay. *J. T. Kingma* 490
Pleistocene and Recent Studies of Waitemata Harbour: Part I—The Main Channel. *E. J. Searle* 501
A Lower Mesozoic Annelid from Rock Point, South-western Wellington, New Zealand. *B. D. Webby* 509
Notes on Four Minor Sulphide Prospects near Coromandel. *David Kear* 514
Some Observations on Night-time Ionospheric Storms at Christchurch. *Ruth F. Mason* 519
A Note on the Age of the Jurassic Flora of Owaka Creek, South-east Otago, New Zealand. *I. G. Speden* 530
Note on the Compressional Angle between Intersecting Transcurrent Clockwise and Anti-clockwise Faults. *G. J. Lensen* 533
Notes on Volcanism and Structure in Franklin County. *J. C. Schofield* 541
Bouguer Anomaly Map of New Zealand. *E. I. Robertson* and *W. I. Reilly* 560
Measurement of Compression and Tension: Some Applications. *G. J. Lensen* 565
A Radiocarbon Date for Penguin Colonization of Cape Hallett, Antarctica. *H. J. Harrington* and *I. C. McKellar* 571
The Antarctic Convergence South of New Zealand. *D. M. Garner* 577

NEW ZEALAND
JOURNAL OF AGRICULTURAL RESEARCH
Volume 1, No. 4, August 1958

CONTENTS

Photosensitivity Diseases in New Zealand: XII—Concentration of the Facial Eczema Poison. *E. P. White* 433
Molybdenum in Relation to the Occurrence of Xanthin Calculi in Sheep. *H. O. Askew* 447
The Use of Chlorpromazine in the Measurement of Radioactive Iodine in the Thyroid Gland of the Rat. *Evan Wright* 455
A Survey of Collar Rot and Root Rot of Cox's Orange Pippin and Other Apple Varieties in Nelson and Marlborough. *C. E. Woodhead* 462
The Goitrogenic Effect of Thousand-headed Kale on Adult Sheep and Rabbits. *Evan Wright* and *D. P. Sinclair* 477
Septoria drummondii Ell. et Ev., a Common Seed-borne Pathogen in European Lines of *Phlox drummondii* Hook. Seed Imported to New Zealand. *H. T. Wenham* 486
Non-toxicity to Animals of Ryegrass Endophyte and Other Endophytic Fungi of New Zealand Grasses. *J. J. Cunningham* 489
Techniques of Measuring Pasture Production in Fertilizer Trials. *I. L. Elliott* and *P. B. Lynch* 498
A Quick Method for Applying Insecticide Dust to Experimental Small Animals. *P. L. Thomas* and *B. O'Grady* 522
Damage by Clover Case-bearer Caterpillars. *J. M. Kelsey* 525
Races of Potato Blight, *Phytophthora infestans* (Mont.) de Bary, in New Zealand. *C. M. Driver* 527
The Use of Condensed Whey as a Food for Fattening Pigs. *A. C. Dunkin* 531
The Effect of Light and Temperature on the Chemical Composition of Pasture Plants. *N. O. Bathurst* and *K. J. Mitchell* 540
Molybdenum Deficiency of the Hop. *H. O. Askew, R. J. Monk,* and *Joyce Watson* 553
Studies of Grazing of Crop Forages by Sheep: I—The Effect of Grazing on Composition, Digestibility, and Nutritive Value of Rape. *A. F. Greenall* 569
Studies on the Thickness and Chemical Composition of the Skin of Sheep. *Manika Wodzicka* 582

NEW ZEALAND JOURNAL OF SCIENCE
Vol. 1, No. 3, September 1958

CONTENTS OF THIS ISSUE

The Contamination of Bacon by Arsenic from Smoke Derived from Preservatized Wood. *C. C. Watson* 361
The Contamination of Fish by Arsenic from Smoke Derived from Preservatized Wood. *C. C. Watson* 369
Mercury Content of Tomatoes. *H. M. Stone* and *P. J. Clark* 373
Determination of Diphenylamine Residues on Apples. *Helen E. Harvey* 378
Notes on Settlement in *Lepas* Barnacles. *T. M. Skerman* 383
The Suspended Plummet Method for Density Measurements. *A. E. Gilmour* 391
Rates of Growth in Two Species of *Lepas* (Cirripedia). *T. M. Skerman* 402
The Detection of Food Preservatives by Paper Chromatography. *Alison C. Cooke* 412
The Collection of *Hylemyia seneciella* (Meade) (Diptera, Muscidae) for Shipment to Australia. *J. M. Hoy* 417
A Note on the Determination of Low Concentrations of Sulphate in Rain and Other Waters. *J. K. Johannesson* 423
The Application of Table Flotation to the Removal of Sulphides from a Scheelite Concentrate. *M. H. Buckenham* and *F. L. Sanderson* 425
Apparatus for Investigating Spatial Distribution of Plankton. *R. M. Cassie* 436
Contributions to the Quaternary History of the New Zealand Flora: Part 1—Auckland Islands Peat Studies. *N. T. Moar* 449
Notes on the Botany of the Auckland Islands. *N. T. Moar* 466
Contributions to the Quaternary History of the New Zealand Flora: Part 2—Plant Remains from a Buried Peat Layer at Bowenwater, Christchurch. *N. T. Moar* 480

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